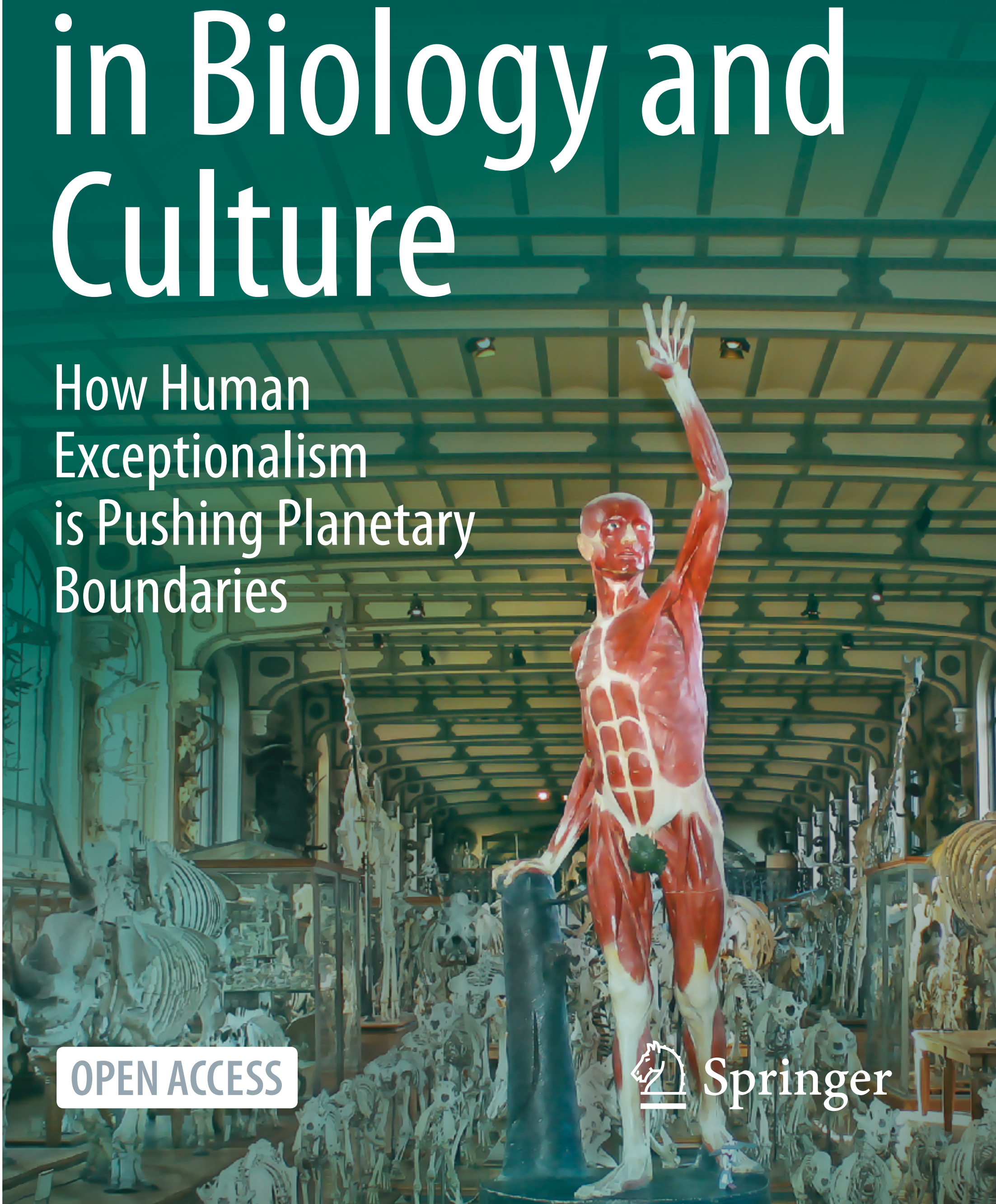
Brian Swartz · Brent D. Mishler
Editors

Speciesism in Biology and Culture

How Human Exceptionalism is Pushing Planetary Boundaries



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Cover illustration: On the cover is a photograph by Brian Swartz, taken at the Galerie de Paléontologie et d'Anatomie Comparée at the MNHN, Paris. Humans are currently in the midst of a 6th mass extinction. Our ego is front and center while skeletonized forms of close relatives lurk in our shadow. We assume we are "better" by our own self-centered standards. Our future carries so much promise. Yet even we are losing our skin, revealing how humans are animals and that humanity is inseparable from the rest of life.

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We dedicate this book to the planet's
beleaguered biodiversity and to the chance
for a bold, sustainable, and abundant future.

Foreword

Homo sapiens compulsively create and label categories—of things and even of ideas. We identify and give names, for example, to mountain peaks, rocks, languages, religions, behaviors, books, subatomic particles, elements, and living creatures. By placing a semblance of order upon what otherwise might be inchoate complexity, communication becomes easier. And, in science, categorization and insight into process have historically advanced in tandem.

In the living world, the widely used hierarchy of categories extends from the molecular and cellular subunits of individual organisms, through organs and other body parts, to the individual, the population, the species, and on up the taxonomic ladder through genus, family, order, class, phylum, kingdom, and then all of life, itself. Finer divisions arise as well, such as subfamilies, superfamilies, and subspecies, all with the same intent: to enhance communication and insight.

There, near the midpoint in the categories of life, sits what is arguably the most widely discussed category of all, at least in biology: species. In the vernacular and in the scientific literature, it is species that exhibit distinct traits, species that go extinct, species we must protect, species that provide ecosystem services, species that need to migrate under global warming if they are to survive, and species that Darwin unraveled the "origin of". Species, species, species… Why? Does a fixation on that category truly abet understanding and communication? If not, what is the alternative? Those and related questions are the focus of this book.

Linnaeus focused attention on species when he invented binomial nomenclature (a generic and a specific epithet that comprise a species name or binomen), and Darwin reified the concept in his classic work. Species are collections of twigs on the evolutionary tree of life that are considered different enough from other collections to be so designated—basically different "kinds" of organisms. It is generally agreed that sexually reproducing organisms that are sympatric (live together) without commonly interbreeding will be considered separate species. But judgments about allopatric populations (those geographically separated) are mostly matters of taste. Basically, species are arbitrary stages in a continuous evolutionary process of population differentiation. Sadly, there is a large silly literature on how to define species that does not recognize this evolutionary fact. An equivalent in silliness would be if geologists generated a long argument in print on how to define a name-able mountain, or if linguists argued about when a dialect should be called a new language, or if theologians argued endlessly about when a heresy becomes a new religion.

Despite the ambiguities, many conceptual categories that are basically chunks of continua with fuzzy borders still prove to be extremely useful—think of red, religious, sick, smart, stream, and so on. Species can be extremely useful as well. Indeed, a quick glance through the pages of The American Naturalist, Ecology, Theoretical Population Biology, Nature, Science, PNAS or any of the other journals that publish ecological research reveals that species are the most commonly used units of analysis. Models predict the forces that lead to the coexistence of some groups of species and the competitive exclusion of other species, or the flow of nutrient across species in a food web. Theories attempt to predict the distribution of abundances and body sizes of individuals across the species in an ecosystem, or the dependence of species richness on area sampled.

In some cases, however, emphasis on species can be really harmful. Perhaps the most important example is that virtually all examinations of extinction rates consider *species* extinctions, whereas *populations* within species are going extinct at rates orders of magnitude higher than those of species. Since it is those populations that deliver the ecosystem services that support civilization, the standard studies lead society to vastly underestimate the threat of the sixth mass extinction episode we are now entering.

Given the problematic nature of the species concept, its overemphasis in some contexts, and especially given the ecological and economic importance of both extant populations and, in an evolutionary context, entire lineages, it is exciting to contemplate the ways in which ecological theory can break loose from the constraints of a narrow focus on species as the organizing unit. As one example, evidence is accumulating, and theory is emerging, that predicts, that species-defined patterns in ecology, such as the distribution of abundances of trees over the species in a forest, depend strongly on the branching structure of the entire taxonomic hierarchy. In the future, those patterns will undoubtedly be shown to depend even more strongly on the structure of phylogenies. These advances provide support for the idea that entire lineages, not just extant species, need to be considered when addressing the classic question in ecology: “What patterns and processes characterize the abundance and distribution of species?”

Looking beyond this, we speculate that truly fundamental theory in ecology must break from the long tradition of rigidly using species as the dominant unit of analysis. Ecological theory that is resilient to the precise way that the units of analysis are defined, that can flexibly accommodate populations as the fundamental unit, or Linnaean units, or functional groups of individuals, or entire lineages, will provide us with the most powerful and convincing means of both understanding how nature works and predicting the probable course of the collapse of diversity and thus of the planetary life support system in the Anthropocene.

The chapters that follow in this book examine the speciesism issue from many different perspectives. We hope you enjoy the insights and find them food for thought in considering how you relate to the living world.

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Preface

This work would not have been possible without the generous support of a Sawyer Seminar grant from the Andrew W. Mellon Foundation. In the midst of a changing world where cross-disciplinary thinking is ever more critical, this project brought together a multitude of diverse minds for fresh thinking on the pressing challenges of our times. Mellon's leadership in seeing the utility of working across fields such as history, politics, law, economics, theology, paleontology, biology, anthropology, and ecology permitted participants to produce something of value that is notably different from the familiar items on our individual CVs. Funding from the Mellon Foundation allowed our thoughts to intertwine in ways that would not have been possible without their support. Mellon's funding also supported open-access publication of this book, which will allow it to reach much broader audiences.

We thank the speakers in the original Mellon-funded Sawyer Seminar Series held in 2012–2013 at the University of California, Berkeley, in order of appearance: Craig Moritz, Brent Mishler, Robert Proctor, Roberta Millstein, David Wake†, Tim White, Tony Barnosky, Jeffrey Boore, Thomas Carlson, Richard Norgaard, Paul Rabinow†, Brian Fagan, Patrick Kirch, Kent Lightfoot, Samuel Lucas, Ken Wachter, John Wilkins, Willis Jenkins, Quayshawn Spencer, Vijaya Nagarajan, Elizabeth Allison, Sam Mickey, Michael Allen, Valerie Eviner, Katherine Suding, Justin Brashares, Gary Steiner, Andrew Light, Joe Guth, Holly Doremus, David Winickoff, Eric Biber, Pamela Ronald, Jonathan Foley, Nathan Sayre, Jennifer Sowerwine, David Zilberman, Clive Hamilton, and Paul Ehrlich.

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We would like to extend a special thanks to Michael Allen, Paul Ehrlich, Scott Fitzpatrick, Saul Griffith, John Harte, Marc Lucht, Nick Matzke, Mark Moffett, Gary Steiner, John Wilkins, and Rasmus Winther for their excellent contributions to this published volume. Their insights and wit allowed more effective integration of our core pursuits. Thank you for how you see the world, for your ability to disarticulate complex subjects, and for your willingness to venture afield into the past, present, and future. On a planet now supporting over eight billion bodies and minds, we appreciate being surrounded by those who care enough to express how life can prosper on Earth and beyond.

Berkeley, USA
December 2022

Brian Swartz
Brent D. Mishler

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Brent D. Mishler is Director of the University and Jepson Herbaria and Distinguished Professor in the Department of Integrative Biology at the University of California, Berkeley, where he teaches about island biology, biodiversity, evolution, and phylogenetic analysis. He received his Ph.D. from Harvard University in 1984. His research interests are in the ecology and evolutionary biology of bryophytes (mosses and liverworts), as well as the theory of phylogenetic systematics. He has been heavily involved in developing electronic resources to present taxonomic and distributional information about plants to the public, with applications to conservation concerns. He has most recently been involved in developing new “spatial phylogenetic” tools for studying biodiversity and endemism using large-scale phylogenies and collection data in a geographic and statistical framework. He is author of over 200 scientific publications, including the recent open-access book: *What, if Anything, are Species?* (CRC Press, 2021).

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Part I
Biology and Culture

Chapter 1
Speciesism, Science, and Society

Brian Swartz and Brent D. Mishler

Abstract Speciesism is to species as racism is to race. The tenets of both are baseless on all grounds. Although our consciousness is currently raised toward the latter, the former remains persistent and infectious. Speciesism begins with how we view ourselves in relation to the natural world, and leads to behavior that challenges our future on this planet. Our naïve exceptionalism has repercussions for ecology, ethics, conservation, law, culture, and the energy and resource base that powers human society. We are merely a part of the natural world, though we have behaved for centuries through a myopia of perceived dominion. By our actions, we are now pushing against a significant number of planetary boundaries, such as threats to natural resources, climate, biodiversity, and the ecological networks that keep humanity afloat. With each passing day, the distinction blurs between the anthroposphere and the ecosphere, between humanity and the earth-system. As transformers of this planet's environment, we are one of the greatest ecosystem engineers the earth has ever seen. Yet we remain dependent upon nature, and how we behave over the next few decades will determine our prosperity on this planet and beyond.

1.1 What is Speciesism?

Academics and the general public largely remain unaware of the concept of speciesism (Jones 2020; Gunderman and White 2021). There certainly exists a familiarity with ethical issues such as factory farming, clearcutting forests, or overfishing. Yet confusion remains about speciesism itself, its underpinnings, and its extensions which transcend the history and future of life on Earth (Fjellstrom 2002; Bindig 2007; Horta 2010; Jaquet 2019). It is the purpose of this chapter, and this book as a

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whole, to expand this discussion and lay a foundation for what emerges from how we view ourselves in relation to the natural world.

If human behavior is our guide, it is clear that we view ourselves as undeniably superior to other living things. The problem is that most people do not realize they have this view, and thus can't easily see the effects that extend into other facets of the human experience (Wilson 2012). Wherever you look in human behavior, speciesism is likely found. It may start with an Instagram post with a person standing on wildflowers thus damaging the very thing they signal to care for. Yet speciesist views extend to a diverse set of topics including: the religious influences that have shaped our self-concepts and global actions; how we treat ecosystems and other organisms; how we grow food and manage the consequences of its production; and how we procure non-living natural resources such as energy that we need to thrive.

While speciesism begins with a selfish notion of perceived human specialness, it extends afield into the future of our existence in the tree of life. We are one lineage (see the definition of this and other terms in Table 1.1) that is genealogically related to millions of other lineages—all living things. Our ancestry has its roots in an extensive genealogy that has been branching and reticulating (merging) for about four billion years. We also share a global environment with all living things. *We are related to, and connected with, the rest of life, and our actions both affect and depend upon our relatives.*

1.1.1 Speciesism: Evolutionary and Ecological Thinking

It is helpful to consider "tree thinking" when visualizing humanity's relationship to other forms of life. This heuristic mindset derives from methods that biologists use to reconstruct the evolutionary relationships among organisms (Baum et al. 2005; Gregory 2008). The branching diagrams that result are called "phylogenies" or "evolutionary trees" (see Fig. 1.1). When we hear about the tree of life—or a lineage, a branch on the tree of life—it is in reference to these kinds of diagrams. "Tree thinking" is about understanding how these diagrams communicate information.

There are specific ways to read, understand, and decipher a phylogeny. For example, in Fig. 1.1, although it is intuitive to read across the tips of the branches, this would lead you to misunderstand what is being conveyed. The tips of each branch refer to living descendants of ancestor–descendant pairs. The diagram does not signal who is ancestral to whom, but rather how recently two tips shared a *common* ancestor. The depth of a shared branch indicates this. For example, you are a descendant of ancestors with a deep familial history. Your siblings and cousins are also a product of this history. Yet no one would argue that you gave rise to your aunt or that your sister came from your brother. Instead, it is a point about recency of common ancestry. You share common ancestors with your siblings (parents), just as you share common ancestors with your aunt (grandparents). These same concepts apply throughout the tree of life.

Table 1.1 A glossary of commonly-used concepts throughout this book

Concept	Meaning	Example
Lineage	Ancestor–descendant relationships through time	Example: Modern cacti are a lineage of flowering plants that share a common ancestor with oaks at one level, with conifers at a deeper level, with ferns at a still deeper level, and so forth. **See** Fig. 1.4. These lineages form the branches on the tree of life Details: Since their origin in the central Andes, cacti have spread into Central and North America across vast stretches of geographic space. Over time, their ancient ancestors gave rise to their modern-day descendants (Guerrero et al. 2019)
Clade	A cross-section of a lineage at a single time	Example: Modern cacti are a clade within flowering plants, flowering plants are a clade within seed plants, seed plants are a clade within vascular plants, and so on. These clades nest within the tree of life, as groups within groups, like Russian dolls Distinction: A lineage has a time dimension, but a clade does not. Clades are *synchronic* cross-sections of lineages, whereas lineages are *diachronic* ancestor–descendant relationships over time. Put another way: a clade is a cross-section (horizontally) through the lineages that descend from a shared common ancestor (Mishler and Wilkins 2018). A close analogy is a single movie frame (synchronic) versus the whole movie (diachronic). **See** Fig. 1.4
Phylogeny	An evolutionary tree (i.e., a phylogenetic tree)	Example: **see** Figs. 1.1–1.2, 1.4–1.5 Details: This is a branching diagram with a vertical time dimension that visually communicates how the tips of the tree relate to one another through common ancestry. The branch lengths shown may reflect changes is characteristics and/or time, depending on how the trees are constructed

(continued)

Table 1.1 (continued)

Concept	Meaning	Example
Taxon	Any formally named group of organisms, traditionally based on various criteria, but in modern phylogenetic classification is restricted to clades	Example: cacti are a taxon of flowering plants, flowering plants are a taxon of seed plants, mammals are a taxon of vertebrates, vertebrates are a taxon of animals, and so on Details: A taxon refers to a group of organisms, which in modern phylogenetic systematics is restricted to monophyletic groups (i.e., clades). A monophyletic group includes only descendants of a common ancestor. Taxon is the singular form of taxa
Taxonomic rank	A particular level in a rank-based classification system	Humans as an example: (*Domain*) eukaryotes, (*Kingdom*) animals, (*Phylum*) chordates, (*Class*) mammals, (*Order*) primates, (*Family*) hominids, (*Genus*) *Homo*, (*Species*) *sapiens* Details: These ranks are human constructs and stem from the pre-evolutionary period of history. They cut across the tree of life at varying depths and do not mean the same thing among groups (Darwin 1859, De Queiroz and Gaulthier 1994). This also applies to any category between the ranks listed above. For example, *SuperOrder* is a rank between *Class* and *Order*, *Subfamily* is a rank between *Family* and *Genus*, and so on. **See** Fig. 1.5
Adaptation	Traits that result from natural selection and increase the relative “fit” between an organism and its environment	Example: Certain groups of cacti exhibit adaptations to arid, dry environments Details: Cacti ancestrally have flat planar leaves. However, water can quickly evaporate across leaves with large surface areas. As cacti spread into drier environments, their leaves were modified into spines, losing the flat planar structure and photosynthetic function, while photosynthesis shifted to their branches. This is why the branches (stems) of desert cacti are green and why they lack planar leaves (Nobel 2002)

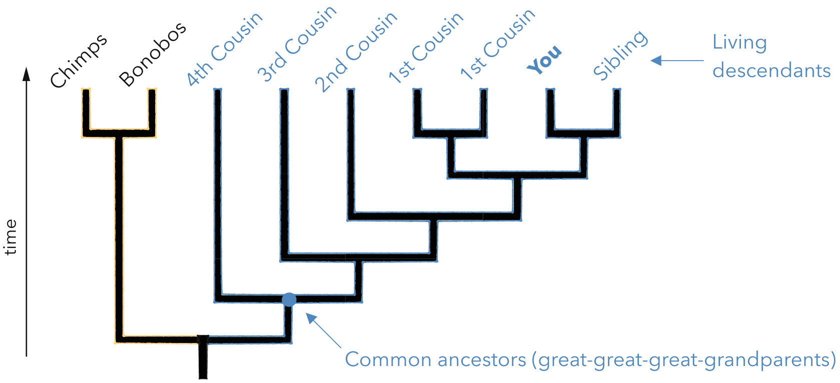


Fig. 1.1 An evolutionary tree showing the relationships among you and your nearest relatives. We do not read across the tips of branches (living descendants) to understand ancestor–descendant relationships. You did not give rise to your sibling nor did you come from your second cousin. You are all descendants of shared common ancestors. A “lineage” refers to these ancestor–descendant pairs. For simplicity, many branches have been excluded that would fall between humans and the other primates depicted

For example, reflecting on the attributes that make you unique—from personality traits to the genetic/environmental influences that shaped you—there is no other person on Earth who can fill your shoes. Comparatively, each branch on the tree of life is also unique. We all have combinations of features that make us special, and no lineage is evolutionarily “higher” or “lower” than any other.

Whereas it may seem true that humanity dominates the planet at a scale not seen by other organisms, the earth has been and likely forever will be dominated by microbes (Gould 1996) (see Fig. 1.2). The tools we use to manipulate nature circle back to remind us how much we remain a part of this microbial world. For example, despite our cleverness, we are running out of antibiotics (Stadler and Dersch 2016). This predicament partly stems from industrial farm animals spending their entire lives on rigorous antibiotic regimes (Anomaly 2015). *We are a tiny branch on the vast tree of life, and share with millions of other branches a network of dependent interactions. Humanity takes massive risks when we fail to consider our modest place in relation to the rest of nature.*

1.1.2 The Scientific Problems with Speciesism

Speciesism carries two fundamental precepts: (1) species are real; (2) one or more of these species are superior to others. The species*ist* embraces both propositions. However, the picture is nuanced and concepts are nested. For example, “species realism” is the view that species are uniquely real (Mishler 2010, 2021; Mishler

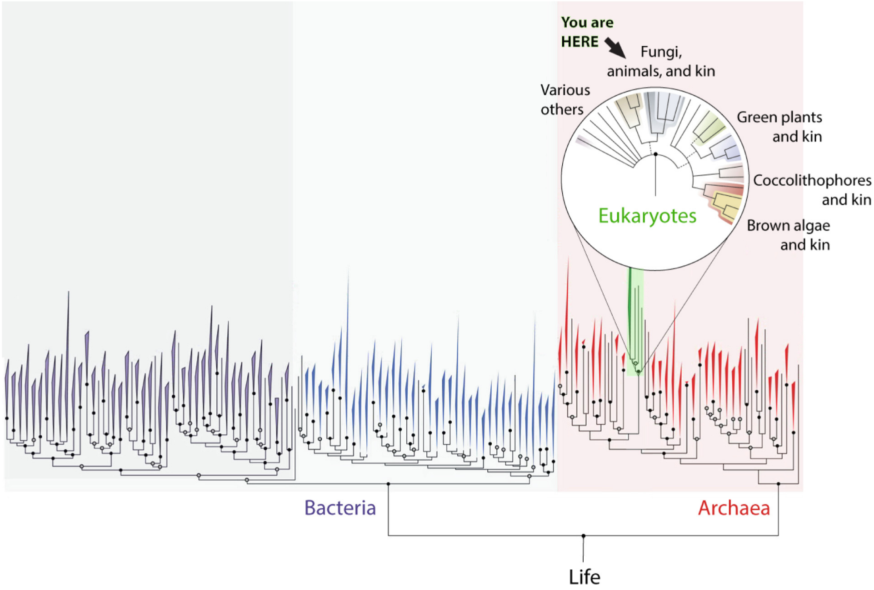
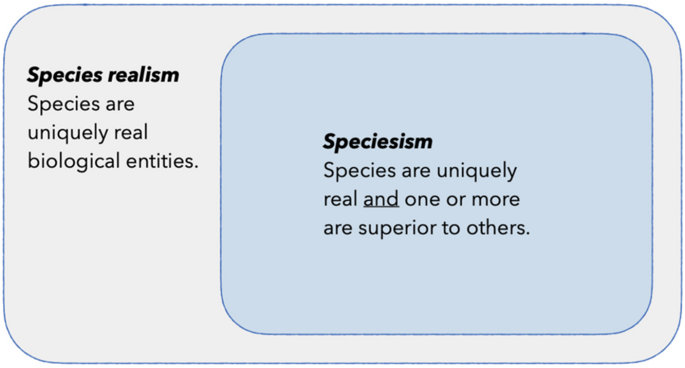


Fig. 1.2 The tree of life, modified from Hug et al. (2016) and Burki et al. (2020). There are two primary branches, Bacteria and Archaea. *Escherichia coli* are a common example of bacteria (in our GI tract). Methanogens are an example of archaeans (in the guts of cows) who produce methane from their GI tracts. Interestingly, as archaeans, humans are more closely related to methanogens than we are related to the *E. coli* in our own guts. Eukaryotes (in green) are Archaea that include organisms like ourselves with a nucleus in their cells (e.g., ALL other animals, plants, fungi, etc.)

and Wilkins 2018), while "speciesism" pairs species realism with an argument for superiority (see Fig. 1.3).

To understand this, it can be helpful to draw an analogy to racism. Racism also carries two precepts: (1) races are real; (2) one or more of these races are superior


Species realism
Species are uniquely real biological entities.

Speciesism
Species are uniquely real and one or more are superior to others.

Fig. 1.3 The conceptual relationship between species realism and speciesism to others. Like speciesism, embracing superiority encompasses the view that races are privileged categories. The parallel does not stop there. Like "species realism," "racialism" views races as biological entities (i.e., as more than cultural constructs; Appiah 1989). One can be a racialist without being a racist as one can be a species realist without being a speciesist. However, the problem with speciesism and racism is that they are both scientifically baseless. But how so?

Consider speciesism in parts: (1) species are uniquely real; (2) at least one species is superior. See Sect. 1.4.1 below for details concerning species concepts in biology. For our purposes here, it suffices to say that whether we focus on sex, anatomy, ecological differences, or phylogeny, no species concept consistently and accurately describes life as it exists across the tree of life (Mishler 2021). It is because of this diversity that we have so many species concepts. The things called species are not uniquely real.

Curiously, we can still recognize real biological "things" across the tree of life. These "things" are lineages and clades, based on ancestor–descendant relationships that on occasion split into separate streams (Mishler and Wilkins 2018). See Table 1.1 and Fig. 1.4 for the distinction between the related but different terms "lineage" and "clade." Ancestor–descendant relationships can be short like those shared between you and your parents or go deep into the past. Sometimes lineages split, other times they merge, and other times they go extinct, but they all together make up the tree of life.

Species realism begins to fail when humans impose taxonomic ranks onto the natural world. For example, a "species" of mammal, a "species" of plant, and a "species" of fungus are not the same thing. Comparatively, the species level is not different from any other taxonomic rank in that every level in the hierarchy is an arbitrary boundary that cuts across the tree of life at variable depths (Mishler 2021)

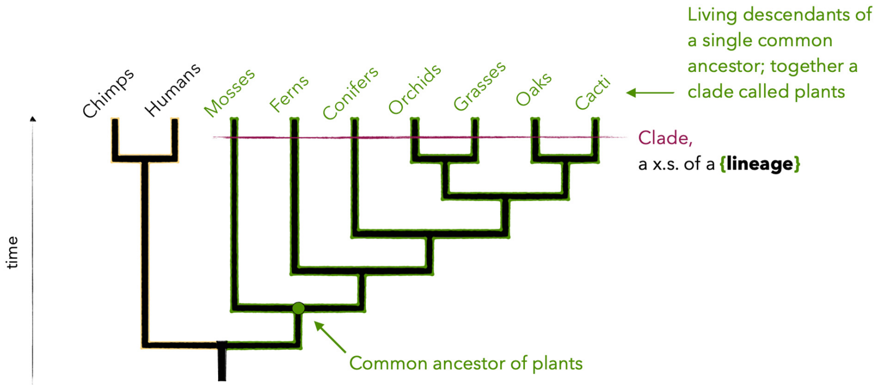


Fig. 1.4 An evolutionary tree showing the relationships among a subset of plants and animals. "Lineages" of plants are illustrated with a black core and green outline, here specifying the branches that connect the common ancestor of plants to its living descendants. A "clade" is a cross-section (x.s.) of these lineages at any level. For simplicity, many branches have been excluded that would fall between those depicted here

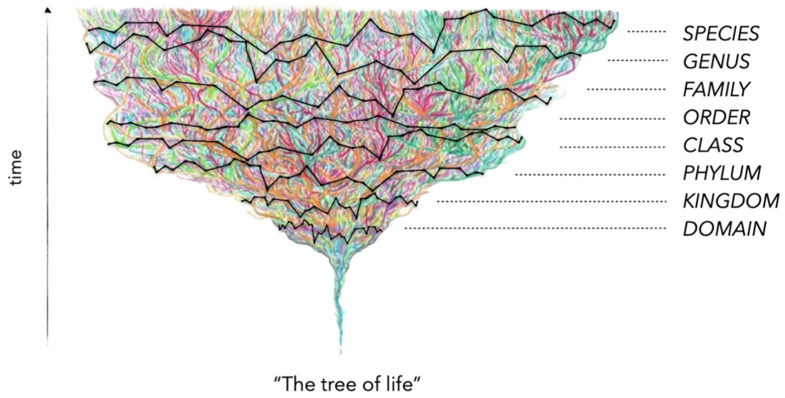


Fig. 1.5 This is the relationship between branches on the tree of life (colored lineages) and the taxonomic levels in the hierarchy (black lines) that humans have used to classify life. Lineages split and merge as they originate and go extinct. These lineages are real biological relationships that connect living things in nested groups. In comparison, taxonomic ranks (e.g., species, genus, etc.) are human constructs that are neither real nor equivalent across groups. The species level is no more special than the genus, family, phylum, or kingdom level. They are all arbitrary cut-offs along a continuum with no privileged position (colored background tree drawn by Karen Klitz)

(see Fig. 1.5). In contrast to species, lineages and clades carry the same meaning in all groups of organisms. Importantly, lineages allow us to measure the earth's biodiversity with precision without ranks, using a measure called "phylogenetic diversity" (Faith 1992; Mishler et al. 2014; Thornhill et al. 2016, 2017; Chap. 8 in this book).

Knowing that lineages make up biodiversity reveals a second issue: the tree of life is fractal. Biodiversity is about branches, from parents and offspring to deep common ancestry. An arbitrary species-level-cut exists across the tree and the depth of this cut varies among groups. This reveals that the species level is not exceptional among a continuum of lineages, bigger or smaller, and that all are important to consider for various purposes including conservation (Mishler and Baldwin 2021).

The arbitrary nature of the species level affects attitudes towards speciesism, of course. One construct cannot be superior to another construct if they are non-corresponding arbitrary entities. If the speciesist proposes the unique reality of species AND embraces superiority then both tenets fall flat. *Lineages make up the tree of life and all extant tips of this tree are equally present today, with none higher, lower, or ethically superior.*

Considering this, let us extend the parallel between species and race. Human races are not distinct branches (lineages) within humans; they are cultural constructs (Templeton 1998, 2013). Members of one so-called "race" are not always closely related. For example, one might look "Caucasian" but be more closely related to a Moroccan cousin than those cousins are related to fellow Africans in Nigeria. Races cannot be superior to others if they do not exist as biological categories. A *socially* constructed group may better at doing a particular thing, but that doesn't mean there is an underlying biological "race" that unites them. Behaviorally, this matters because how we see ourselves influences how we treat other people (racism) and how we treat other living things (speciesism).

One lineage may be empirically superior to other lineages in a specific functional trait, of course (e.g., eagles have better eyesight than humans). Yet it is essential to remember that adaptations (see Table 1.1) are about the relationship between an organism's traits and its environment (Darwin 1859). Adaptation is not universal across all traits, and there are constraints imposed by developmental relationships among traits. Humans have a mixture of traits like all other organisms, some "good" traits and some "bad" (Gould and Lewontin 1979). We may be unable to fly like bats or swim like whales, but we have a gift of foresight and planning. We are working hard to promote sustainability and venture afield on an interplanetary scale. However, aspects of our intelligence may be maladaptive in the arc of humanity's future. We are capable of some of the most astonishing accomplishments, but as emotional animals, our minds often hijack themselves (Asma and Gabriel 2019). What the future holds within our prevailing environment is an experiment in progress.

Until then, we must be keenly aware of speciesism during this time of perceived dominion. Human beings are probably the most dominant ecosystem engineers the earth has ever seen. However, we are also the worst "weed" the world has had to deal with. Over the last few hundred years, virtually no part of this planet has gone untouched. Whether we consider the energy and resources that fuel civilization or the larger earth-system that we expand into, the effects of our behavior are profound (Rockström et al. 2009; Hughes et al. 2013; O'Neill et al. 2018). Why do we behave as we do? Why do we assume that we have the right to modify the planet as we wish and subjugate other living things to our needs? We often overlook intrinsic values in organisms and natural resources ("intrinsic" as in something special about an entity in question) and instead pursue instrumental values (values that relate solely to our benefit) (Moffett 2020). *Our unquestioning attitudes about dominion over the rest of nature are strikingly similar to the unquestioning attitudes held by dominant cultures throughout history about their dominion over the rest of humanity.*

There is little doubt that we love ourselves to the exclusion of others. Perhaps this is understandable as a form of "us versus them" thinking that derives from our evolutionary past. But these tendencies cost us tremendously within the modern world (e.g., race, religion, politics) and across the tree of life (e.g., extinctions, loss of ecosystems, global climate change). As a civilization, we do not hide, or even realize the depths of our perceived superiority. We view ourselves as "better" than the rest of life.

Human actions indeed reveal deep seated speciesism. Grounding us in the natural world is probably the first best step toward dethroning our misguided exceptionalism. For millennia, we have constructed ideas and belief systems that position us at the "top" of life on Earth (Lovejoy 1963). These beliefs have placed *Homo sapiens* (wise man) as THE animal to "fill the earth and subdue it," to "have dominion over the fish of the sea and…over every living thing" (Genesis 1:28). We have done precisely this. For years, humans have debated what makes us special, be it language, tool use, culture, consciousness—all shades in a continuum with parallels and antecedents in other organisms (Lieberman 2013; Bickerton 2014; Tomasello 2014). However, there is one distinguishing point that makes the case for itself: we are likely the only organism, ever, that has spent mental effort trying to convince itself of just how exceptional it is.

1.2 A Sawyer Seminar Funded by the Andrew W. Mellon Foundation

This volume stems from a seminar series on speciesism held in 2012–2013 at the University of California, Berkeley, funded by the A.W. Mellon Foundation. This book follows the same format as the original seminar series by viewing speciesism in light of biology, culture, history, conservation, law, and sustainability. We have kept many of the same topics, though we have added new topics in the spirit of our times (e.g., the social concept of race, pandemic diseases, and the future of food and energy). Some of the seminar speakers contributed chapters to this book, and we invited additional scholars to contribute.

We first unpack speciesism by rooting humanity within the tree of life. Doing this allows us to see the evolutionary and ecological themes that connect our lineage with the rest of life. We expand this by revisiting early human civilizations to understand how smaller societies behaved on islands as humanity now acts globally. Throughout human history, islands have been microcosms of present impacts. This dissection of a “historical small” within a “current big” makes human actions tangible and clarifies how we repeat old behaviors. Will we continue these antics as we pursue interplanetary travel and treat planets as new microcosms within the universe? What insights exist in this landscape of past mistakes and future visions?

We then look into how humans are treating the current world. What does human behavior say about how we value forest resources (FAO 2020a), ocean resources (FAO 2020b), and the free services (e.g., pollination, photosynthesis, air to breathe, climate regulation, etc.) that come when these environments are intact (FAO 2020c)? How are we treating domesticated plants and animals, including soils that these organisms grow in or live upon? How do our cultural systems (e.g., religious, industrial, political, legal, medical) align with and extend from human-environment interactions? What do our cultural systems reveal about what we value? In medicine, if our microbiome (the totality of microorganisms that live in and on us) slightly outnumbers our cells by a ratio of about 1.3:1, then what does this say about what it means to be human, yet alone a “species?”

In the current landscape of pandemics and zoonotic diseases (diseases transferred between human and non-human animals), how is our perceived exceptionalism accelerating global problems? As the human population grows and we consume more resources, city centers become more dense. How will this affect our management of contagious diseases? How will we feed this world? How will energy power this future? Like any complex open system, human civilization requires energy. As we strive to wean ourselves off fossil fuels, what clean and sustainable alternatives will power a society that remains dependent upon the laws of physics? These are all questions that inevitably flow from understanding speciesism and its consequences.

1.3 Major Topics Related to Speciesism Covered in This Book

The chapters in this book follow the arc of the original seminar series, although with expanded breadth. Major themes include alignments between speciesism and racism; connections to ecology and evolution; behavioral antecedents in human prehistory; the influence of religion on human perception in relation to nature; the role of symbols as social meanings in humans and other animals; current ethical and legal manifestations as an extension of human behavior; the affects of speciesism in conservation biology; and the civilizational consequences of human actions on interplanetary scales. In this section we give short summaries of the other chapters in the book. In the following Sect. 1.4 we discuss a few additional topics that are not represented by separate chapters in the book.

1.3.1 Race and Human Genomic Variation, *Rasmus Winther*

In his chapter, Winther shows that we differ genetically far less than intuitions suggest. Compared to our differences with close relatives, there is relatively little genomic variation within *Homo sapiens*. Among the 3 billion base pairs (DNA letters) that compose our genomes (one from each parent), they are 99.9% identical among all humans. Interestingly, African genomic variation is the richest and most distinctive among all continents. Further, this pattern continually decreases as geographic distance from Africa increases; we vary less as we move away from Africa. In essence, we are all Africans, despite superficial differences in appearance or skin pigmentation.

Winther invites us to see that surface-level variants should not matter ethically or politically. If we differ by only 0.1% at most, with most differences in Africa itself, what does this say about the biological core of humanity? We are fundamentally the same. What does this imply about the basis of racism? It is empirically unfounded.

How can we pull from this insight to rally around a unified cause, a shared vision for a shared future, as members of a single lineage (*Homo sapiens*) trying to manage its existence on a finite planet? This question is more complicated, yet if we can embrace our homogeneity and act, then perhaps we can start behaving as though our future depends upon it. How we treat the world and each other affects all that we engage with, especially when our actions affect prosperity.

1.3.2 Science Without Species, Nicholas J. Matzke

In recent decades evolutionary biology has begun to move away from species as the key unit of analysis to address biological questions. In this chapter, Matzke begins by outlining how phylogenetic comparative methods have become essential tools in statistical analyses of trait relationships. Species are not statistically independent observations because they are related to different degrees on a phylogenetic tree. In fact, moving to a phylogenetic view of biodiversity can avoid a number of problems created by attempting to impose a uniform species rank across different geographic regions and clades. A major challenge in modern studies of diversification and extinction is the units of analysis and how they are defined and recognized. Taxonomic ranks including "genus" and "species" are human-defined levels imposed on a phylogenetic tree. The tree itself is the reality produced by the macroevolutionary process, and it includes every level of gradation in evolutionary divergence. Once ranks are imposed upon it, a variety of methodological problems are created as scientists compare ranks across datasets and timescales. Phylogenetic thinking can provide a solution. Matzke concludes this chapter with examples where cutting-edge science is done without need of the "species" rank.

1.3.3 Islands as Microcosms of Human Impact, Scott M. Fitzpatrick

The colonization of islands by humans in the ancient past provides study systems for human impacts on a manageable scale. In this chapter, Fitzpatrick initially focuses on the vast expanse of the Pacific, where beginning ca. 3000 years ago, Micronesian and Polynesian voyagers colonized the most remote, and final places to be reached by humans. The biota of these islands evolved independently for thousands or even millions of years, resulting in high rates of endemism and extremely fragile ecologies. The first arrival of *Homo sapiens* caused a wide variety of impacts that were greatly amplified later with Euro-American incursion. As ecologically bounded places, islands thus serve as model systems for how humans affect the earth's biosphere in the modern age.

Fitzpatrick takes this concept further, suggesting that the processes involved in the prehistoric colonization of islands are a corollary for current global impacts and extraplanetary colonization. As the possibility of extraplanetary migration becomes a reality—perhaps even a necessity to ensure our survival—Fitzpatrick invites us to ask what lessons we can learn from the archaeological study of islands. What are the consequences for us and for other forms of life on this planet and possibly others? Will we learn from our mistakes or will we bring them with us? The earth is only one of many habitable islands in the larger cosmos. How will we manage the present manifestations of human behavior, growth, sustainability, economics, ethics, disease, density, and the future of food and energy?

1.3.4 Species, God, and Dominion, John S. Wilkins

In this chapter, Wilkins argues that having a "theoretical" notion of species causes harm to science and polity. He clarifies that species as a concept is the result of theological and philosophical considerations, with deep historical roots, not any current empirical or scientific need. Yet the idea of biodiversity existing as bounded species units still holds political importance for religious ideas of *dominionism*, or supposed human supremacy over nature. It also carries tremendous impact on environmentalist and conservationist politics in the United States and elsewhere. Fundamentally, as Wilkins explains, the current concept of species is damaging since it retains much of its essentialist religious origins and emphasizes human exceptionalism to the detriment of expanding our attitudes about the rest of life.

1.3.5 Symbols and How We Came to Be Human, Mark W. Moffett

A major belief behind the idea of human exceptionalism is that *Homo sapiens* is distinct from other taxa in our use of symbols. In this chapter, Moffett considers the concept of "symbols" to describe anything with a socially shared meaning but without obvious ecological utility. Countering the argument that symbols are unique to humans, Moffett proposes that they be recognized as agents in other animals that operate in a diversity of ecologically meaningless "social markers." For example, broadly speaking, social markers might signal ingroup versus outgroup identity, and manifest in ways similar to how humans posture as they walk, express emotions, or use scents or cultural ornaments to decorate their bodies.

What does the broad tendency for "marking" traits suggest about the evolutionary origins of symbolism? Moffett critiques views of human symbolism expressed by sociologists, psychologists, anthropologists, archaeologists, and biologists. Instead, he proposes that symbolism might have arisen from behaviors in other animals which live in societies bound together by simpler "markers" of identity, such a group scents or vocalizations that do not convey ecological significance. Importantly, such markers can be essential for holding societies together.

1.3.6 Human, Non-Human, and Ecosystem Rights, Gary Steiner and Marc Lucht

Western philosophical tradition has long maintained that only humans can possess rights. In this view, attributing rights to non-human animals is dubious and attributing rights to the non-sentient natural world in nonsensical. However, in their chapter, Steiner and Lucht analyze the commitments motivating this conception of rights and reveal that it is based on self-centered prejudices of humans that their own type of sentience is required for full moral status. Steiner and Lucht show how recent research has elucidated the intellectual and emotional lives of other animals, making it necessary to rethink their moral status. More radically, they show how rejecting anthropocentrism opens the door to recognizing that certain non-living entities also deserve moral consideration and have rights to respect. The differences between the traditional and the new approach to rights draws into question the conditions for moral worth and highlights our need for a satisfactory theory of the world and understanding of the proper place for humanity within it.

1.3.7 A Phylogenetic Approach to Conservation: Michael F. Allen and Brent D. Mishler

As late as the sixteenth century, the world was a matrix of wild lands. Due to rapidly increasing technological development and population growth, we increasingly subjugated and diminished the natural world. By the eighteenth and nineteenth centuries, some pushback occurred, with calls emerging for conservation. National parks were established and laws passed that were designed to save endangered species. In this chapter, Allen and Mishler show that while the "one species at a time" approach can be credited with saving many individual taxa, it is insufficient to deal with the current biodiversity crisis given urgent pressures on remaining natural lands. They advocate moving from a "single-species approach" to an "area-based approach" that incorporates a broad phylogenetic definition of biodiversity. Biodiversity conservation should not focus on the arbitrary level at which species are named. Instead, it should be focused on the whole tree of life. Allen and Mishler discuss new spatial phylogenetic tools that leverage recently available DNA and geographic data, plus new computational tools, to incorporate all levels in the tree of life when making conservation decisions. To protect biodiversity amid increasing environmental impacts, we need to adopt cutting edge strategies for conservation to allow life to thrive and ecosystems to function.

1.3.8 Energy and Society: Toward a Sustainable Future, Saul Griffith

Energy is the single greatest lever that moves civilization. As a society, we have pulled upon fossil fuels as a historical source of energy, but have begun transitioning toward alternatives. In this chapter, Griffith explores our global move toward alternative energy, its feasibility and impacts, and the kind of world we can create with a decarbonized and electrified future. He considers how much energy we actually need, and evaluates alternative sources of energy including nuclear power. Then he examines what the effects of achieving a sustainable energy future would be, including impacts on biodiversity and land use. Throughout the chapter, Griffith explores how to achieve sustainability while avoiding destruction of the rest of biodiversity and positively uplifting humanity.

1.4 Other Topics Related to Speciesism

Speciesism connects to a variety of other subjects that we were not able to include as chapters in the book. Thus, we give an encapsulated treatment below of the nature of biodiversity, human population, health, medicine, and the integrative future of food.

1.4.1 Species, the Arbitrary Constructs of Biodiversity

It was Darwin (1859) who first realized that the species level is not unique. As he saw it, lineages diverge for various reasons, though at some point (out of convenience), a taxonomist decides to call a lineage a species even though nothing fundamental happened at that point in divergence. By the early-mid twentieth century, evolutionary biologists such as Theodosius Dobzhansky and Ernst Mayr reintroduced species as a "unique" level (Dobzhansky 1937; Mayr 1982). They used their "Biological Species Concept" (BSC), proposing that interbreeding is the key criterion that happens uniquely within species (see Mishler 2010 for detailed discussion).

However, the recent availability of extensive genetic data within and between named species makes it abundantly clear that Darwin was right and the BSC does not apply in plants, animals, or microbes. Interbreeding and other forms of horizontal gene transfer (i.e., genetic exchange across lineages, distinct from the normal vertical transmission between ancestors and descendants) happens at multiple hierarchical levels across all life (Husnik et al. 2021). Contrariwise, there is a lack of interbreeding at many levels as well (Mishler and Donoghue 1982). There is no magical "species level" where rampant interbreeding abruptly transitions to no interbreeding. Instead, there are nested clades that are smaller and larger than the traditional species level that play essential roles in ecology and evolution.

In other words, the situation is richer and more interesting than the BSC took into account. A multi-level approach is a more accurate way to study the origin, maintenance, and conservation of biodiversity (Mishler 2021). A similar suite of processes act at various levels in the tree of life, albeit with a balance that shifts in exciting ways at various levels in different parts of the tree. A revolution in many areas of study (e.g., diversification, niche evolution, biogeography, coevolution, and conservation) will follow once a multi-level view replaces a rigid focus on the species level or other taxonomic ranks (Mishler 2022).

Granted, present methods based on taxonomic ranks do provide a rough estimate of diversity over time. In paleobiology for example, ranks provide utility since they allow discovery of patterns and processes that regulate global biodiversity (Sepkoski et al. 1981; Alroy et al. 2008, Barnosky et al. 2010). Current methods enable practitioners to reveal major historical events even if the ranks are arbitrary. For example, there have been five mass extinctions over the last 541 million years (e.g., via extraterrestrial impacts, widespread volcanic eruptions, climatic events that followed, sea-level changes, etc.). We can discover how environments and taxonomic groups were affected by these global changes. There has been fruitful research in this space, even as it aligns with the sixth mass extinction of the present day (Barnosky et al. 2010). In context, ranks represent diversity at some level and carry some utility when insufficient data make it hard to resolve phylogenetic relationships. This does not mean that ranks are natural categories, though they do allow us to roughly estimate biodiversity in the fossil record.

However, to measure diversity with the greatest precision, "systematics" (the discipline for classifying life) needs to move towards naming only clades, while eliminating ranks, including species. Much progress has been made towards that goal. The newly published *PhyloCode* (Cantino and de Queiroz 2020) is a major step in that direction, but it is still not logically complete since the species rank remains embedded within it. The community of *PhyloCode* supporters is split on this (Cellinese, Baum, & Mishler 2012), and it will be interesting to see if the *PhyloCode* can further evolve to become completely rankless as advocated by Mishler and Wilkins (2018).

Whether the species rank is formally eliminated or not, it is important to understand that the species level is arbitrary and that different entities called species have nothing necessarily in common. Instead of viewing biodiversity as "the set of species on Earth," we should view biodiversity as "the entire tree of life," with branches at many different levels having interest and import. *Humans are literally related to all other living things, which should affect our ethics and inform how we treat them.* The sooner we can wrap our minds around this truth, the sooner we can understand the concepts and processes at play. This realization allows us to see what speciesism means and how it weaves into the biological and cultural manifestations that emerge from it.

1.4.2 Human Population

About 300,000 years ago, *Homo sapiens* split from other branches of the *Homo* lineage (Hublin et al. 2017). Yet our origin did not proceed without extensive interbreeding (reticulation) with Neanderthals as far back as 100,000 years ago (Bergström et al. 2021). It took every year of these 300,000 for the human population to reach one billion. That happened in the year 1800. Since then, our population has grown exponentially, reaching two billion (1927), three billion (1960), four billion (1974), five billion (1987), and today (2022) has just passed eight billion. Growth rates have slowed despite the ongoing upward trajectory (Vollset et al. 2020), but many challenges have surfaced as the human population has swelled (Bradshaw et al. 2021).

The current balance between birth and death rates explains population growth rate. However, this is not the full story about environmental impacts since per capita consumption varies widely. In developing countries, birth and death rates are often higher than in developed countries, but citizens of the developed world consume many more resources on average (UNDP 2020). The balance between reproduction and consumption provides insights into our resource footprint and the number of people the earth can sustain (carrying capacity). Data suggest that we currently consume resources as if we lived on ~1.75 Earths (Global Footprint Network 2020), even though there is only… one. The earth's carrying capacity for humans is not well understood (Cohen 1995). Most published estimates suggest that it is between 8 and 16 billion (Pengra 2012). However, we have changed our carrying capacity multiple times throughout history (Goudie 2019). Since at least the industrial revolution, we consumed energy and natural resources to fuel a growing civilization (Crutzen 2002; Crutzen and Steffen 2003; Hoekstra and Wiedmann 2014). Current growth and consumption rates are unsustainable, but where are the limits and how are the resource inputs changing? *This partly depends on what standard of living is acceptable and on the accelerating rate of technological change. Is the goal to keep people alive, or some higher standard that includes space, amenities, and opportunities for humanity and the rest of biodiversity?*

One challenge is that even though developing countries have higher birth rates, the impact of each person on the environment is much greater in developed countries (UNEP and IRP 2011; Kampang and Shaoqi 2012). In part, this is why sustainable economic growth is key to many aspects of human wellbeing. If population growth outpaces economic growth, the consequence is slum-like environments where essential services are sacrificed, such as sanitation, law, medical care, clean water, etc. (Oof and Phua 2007). These environments become grounds for poverty, disease, and suffering (Marmot et al. 2008). This is a tremendous reason to support developing countries, to keep their economies sustainable, their environments intact, and to reduce birth rates while increasing prosperity. Much about human health is intimately connected to the economic, environmental, policy, and values-based decisions that accompany a growing civilization (FAO 2020d; Vollset et al. 2020).

Thus, we have many goals for the pivotal year of 2050. These include transitioning to alternative forms of energy, managing the global climate, conserving natural resources, combatting food security, leveraging exponential technologies, among countless others (Hubert et al. 2010; Griggs et al. 2013; Gates 2021). It is clear that one important way to improve prosperity is to give equal rights to women, enable their voice in decisions on family size, and provide education and healthcare to all. Around the world, data show that birth rates decrease as these resources are provided (United Nations 2017). Compassion is a precious thing, especially when the consumption of energy and natural resources has driven our economic path. We are victims of our success in many ways.

Even as birth rates decrease and societies transition demographically, greater affluence increases global consumption. Reproduction and consumption are thus interdependent, even in a sustainable world with a healthy human population and a diverse environment. By 2050, there will be about two billion more humans on Earth, for a total of about 10 billion. It will increasingly stress our infrastructure to sustain this civilization while managing the climatic, energetic, and environmental impacts that currently result from our "business as usual" path (Griggs et al. 2013; United Nations 2017).

This is one reason why it's crucial to leverage information technology and to accelerate the rate of information that we discover and return to civilization (Kurzweil 2004, 2005). Artificial intelligence, machine learning, blockchain technology, materials science, and quantum computing are examples of such tools (Kissinger et al. 2021). The compounding rate of innovation can thus permit an abundant future by changing the inputs and outputs to engineer prosperity (Diamandis and Kotler 2012, 2015, 2020; Bastani 2019). In contrast to the pace of government and policy decisions, significantly moving this dial is about catalyzing human behavior change by applying current and new technologies for the human population at scale.

1.4.3 Public Health and Medical Implications

There are health consequences that connect to every aspect of population growth at this scale. Examples include: air pollution that results from the tools that power civilization (e.g., combusted byproducts of fossil fuels, airborne industrial and agricultural wastes); climate-related extreme weather events (e.g., floods, fires, hurricanes); vector-borne diseases that spread poleward from the tropics as climate belts shift (e.g., dengue fever, West Nile virus, Rift Valley Fever); environmental toxics that accumulate and magnify in regional environments and human bodies (e.g., endocrine disruptors, carcinogens, heavy metals); challenges growing food via traditional agriculture (e.g., the depletion of soil nutrients, plants living in environments they are not adapted to, the environmental and health impacts of agricultural techniques); and the stressful mental health issues that people face amidst these challenges (WHO 2021a). In a world where the biology of stress approximates the biology of western diseases (Sapolsky 2004, 2005), what looming public health crises exist over the horizon?

Late 2019 saw an unprecedented public health crisis: SARS-CoV-2, the virus that causes COVID-19 (coronavirus disease 2019). Research into the origin of this coronavirus is ongoing (Anderson et al. 2020; Rasmussen 2021; Sallard et al. 2021; Segreto and Deigin 2021; Segreto et al. 2021; Shi 2021). Whatever the origins turn out to be, one message is simple: human population densities are as critical to public and environmental health as is the total size of our population. Both have signals that underpin sustainability and wellbeing. Harvesting resources, including wildlife, as we encroach on natural habitats increases the likelihood of encountering zoonotic diseases (i.e., the transfer of disease agents to humans from other animals; Rulli et al. 2021). We also live in a connected world where humans move and where densities can be high. Pathogens function best in these environments. This is why "social distancing" reemerged as a phenomenon in 2019, to decrease population densities (e.g., "6 feet apart") and lower transmission likelihood.

We are no longer hunter-gatherers in a low-density world. The anthroposphere (the ecological landscape we have created) provides new situations for opportunistic microorganisms. Human culture transforms ancestral environments and microbes take advantage of shifting landscapes. It is a case when worlds collide. Humans are spectacular ecosystem engineers but there are other players on this chessboard (Darwin 1859; Van Valen 1973). Moves are met with countermoves, even if we didn't anticipate them. While we sink our wedge deeper into this landscape (acquiring resources while displacing others), microbial players discover our vulnerabilities. 2019 revealed that these opportunists can cause global pandemics, kill millions of people, and bring economies to near standstills.

It is striking to consider how viruses reproduce in the first place (V'kovski et al. 2021). They require host cells to replicate. They inject their DNA into the genome of a host, thereby hijacking its cellular machinery and instructing it to make viruses. This process doesn't just allow viruses to reproduce. It also leaves behind a fraction of viral DNA. It is estimated that about 8% of the human genome is viral DNA (Belshaw et al. 2004; Jern and Coffin 2008). This genetic intermixing produces an outcome that can be compared to other ways that organisms reproduce. For example, animals primarily reproduce from sperm and egg. This means that DNA in the offspring comes from the merging of paternal and maternal sources. Sexual versus viral reproduction are obviously different, but the pattern is much the same: lineages coalesce and exchange DNA at various points across the tree of life.

The frequent merging of lineages over evolutionary time illustrates how erroneous it is to think that species are uniquely real units because DNA is only shared within the same species (Mayr 1982). Evolution is about lineages, forward to the present and back to the past. They split, they merge, they go extinct; tree thinking is core to understanding this. What value does focusing on the classical species level bring to considerations of reticulation and zoonotic diseases? None: it diverts our attention from grasping the processes at play, the levels involved, the patterns that emerge, and applying this knowledge to discover tools to manage pandemic diseases.

2019 exposed us to a new lineage of coronavirus that slowed humanity to a near standstill. Its genes merged with ours and killed over five million people in two years (WHO 2021b). A pandemic at this scale was predicted during the previous decade (Gates 2015). Let COVID remind us that we are neither superior to, nor separate from, the rest of life on Earth.

1.4.4 Food: Nutrition, Energy, Climate, and Biotechnology

The future of food is among the most integrative subjects of our time. It includes connections that weave through nearly every facet of the global environment, and speciesism resides at its core. How we see ourselves in relation to nature determines how we treat other organisms, how we view habitats that foods come from, the methods we use to capture or cultivate these foods, and the civilizational consequences of our actions. Food entwines subjects such as energy (Pimentel and Pimental 2007), climate (Rosenzweig et al. 2020), biodiversity (Worm et al. 2006; Crist et al. 2017), soil health (McBratney et al. 2014), ocean health (Halpern et al. 2015), biotechnology (Steinwand and Ronald 2020), nutrition (Domingo et al. 2021; Meyers et al. 2017), the future of contagious diseases (Rulli et al. 2021), and the ethics that guide human behavior in these spaces (Wilson 2012).

One of humanity's grand challenges over the next 30 years will be growing food sustainably for a population of about 10 billion. The food system is a subset of human ecology, an economy of nature powered by energy. At present, fossil fuels provide most of the energy that drives food production and distribution (Shukla et al. 2019). Our food is either wild caught (e.g., fishes) or grown (e.g., agriculture or aquaculture). Amidst a more extensive energy transition, we are working to wean ourselves off fossil fuels and power all of civilization (including food) via sustainable alternatives. Yet in the meantime, about one-quarter of our carbon footprint comes from food production and how we use the land it grows upon (Ritchie and Roser 2020). Trying to feed everyone carries tremendous potential to impact the global climate and biodiversity. Presently, industrial agriculture functions ineffectively at mitigating the ethical, environmental, and public health effects of food production. This appears as deforestation, habitat loss, overfishing, monocultures, biocide and fertilizer overuse, nutrient runoff into coastal dead zones, desertification of farmed soils, depletion of soil nutrients, groundwater depletion, and the government subsidies that incentivize many of these methods (FAO 2020a, b, c, d, e). We can do better.

We are beginning to produce food using more healthy and sustainable tools. While the global energy landscape is transitioning toward alternatives, the food landscape is changing as well. Regenerative agriculture helps to mimic natural ecosystems (cycling nutrients back to their environments) while sequestering carbon from the atmosphere and giving healthy lives to farm animals that allow this to happen (Duncan 2016; Lal 2021). Hydroponics and aquaponics provide tools for growing plants indoors without abusing farmed soils with chemical fertilizers, groundwater depletion, and widespread biocide use. Healthy aquacultures are also becoming common, with algae at the base of their food systems in contrast to food pellets made from corn, soybeans, or reef fishes (Goddek et al. 2019). As a form of cellular agriculture, cultured meats are also growing (literally). We are discovering more effective ways to financially and energetically grow muscle cells to make cultured alternatives to what would otherwise emerge from a factory farm (Humbird 2020; Triech 2021). For the first time in history, cultured meats carry the potential to create food from plant and animal cells and to make many unethical practices of the modern industrial farm disappear.

Unfortunately, "ecological thinking" has challenged food production technologies since the Industrial Revolution. In modern forms, this might manifest as raising salmon or cows on a diet of corn. This diet increases the concentration of pro-inflammatory omega-6 fats because it skews the omega-3:6 ratio in their tissues (Simopoulos 2003). This happens because corn plants store omega-6 fats as energy for young seedlings, fueling their growth and the eventual synthesis of green photosynthetic leaves. Plants need a source of energy to germinate before they can begin photosynthesizing in the first place (Ai and Jane 2016). Yet when we take these foods out of context and feed them to organisms who are not adapted to them, we introduce a state of mismatch into their environments and ours. We are the next level up in this food chain, and a tighter balance of omega-3:6 is optimal for human health (DiNicolantonio and O'Keefe 2018; Taha 2020). Given the ramifications, why not first consider ecology when making food production decisions? Further, energetically, it would be better yet to skip feeding plants to animals and to eat the plants directly (Bonhommeau et al. 2013). This ecology-first approach is one great benefit from regenerative farming, which treats food systems as natural ecosystems.

Further, what can we learn from supplement markets that often extract "active ingredients" and reduce them to molecules? Do these molecules always carry the same physiological effects as their counterparts in food? For example, do omega-3 pills carry the same benefits as eating wild-caught fatty fish (ASCEND 2018, Aung et al. 2018; Bhatt et al. 2019; Hu et al. 2019; Manson et al. 2019)? Synergistic effects often emerge when eating whole foods, which can be lost when reduced to molecular building blocks (Pollan 2008). Considering the promise of cultured foods—whether as lab-grown muscle cells (from animals) or lab-grown meats (from plants)—we must think hierarchically to optimize outcomes. This framework transcends molecular, cellular, and organismic physiology. The hierarchy of food production matters since food scientists use individual molecules to enhance flavor or texture, in addition to biotechnological tools to source whole food constituents (e.g., a genetic lineage of maximally healthy muscle cells) (MacQueen et al. 2019; Furuhashi et al. 2021). If we are tailor-making plant-based steaks to create the "marbling" that people want (using omega-6 rich sunflower oils), then we must evaluate the public health consequences of our ingredients (Southey 2021; van Vliet et al. 2021). Do we want the equivalent of corn-feed beef because we did not take an appropriately integrative approach when culturing food?

We need to be careful not to create a public health crisis while trying to feed humanity. At scale, this is precisely what is happening with industrial agriculture. Most current agricultural staples are easily digestible carbohydrates that contribute to obesity, type 2 diabetes, metabolic syndrome, among various health problems (Taubes 2007; FAO 2020e; FAO et al. 2020). Therefore, the future of food is also about the ethics of human rights and giving people quality products that optimize health. If a goal over the next 30 years is to sustainably feed humanity without creating environmental or health crises, then there is much potential to flourish. Let us learn from current oversights so that we do not introduce them into innovative technologies. This applies to how food production affects the global environment and public health, and extends to zoonotic diseases and ethics as well.

Probably the greatest promise of emerging food technologies is the potential to feed humanity at scale without contributing to the environmental and ethical problems that underpin current mainstream practices. We will need a portfolio involving a combination of methods described above. With those in place, the risk of pandemic diseases, environmental impacts, and ethical mistreatment decreases. By their nature, zoonoses are diseases that humans catch from other animals. With regenerative farming practices and cultured foods from lab-controlled environments, the likelihood of zoonoses becomes exceedingly small. Comparatively, high-density farms and wild-caught animals present a vastly greater risk category. In addition, the potential for animal suffering approaches near-zero with cultured meats at the cellular level. At the organismic level, regenerative farms provide healthy environments and quality lives for domesticated animals to live and thrive in their ecosystems.

In summary, while it is important to feed the people, we also need to cease wildland conversion to agriculture and minimize all other impacts on wild biodiversity. Further, we should emphasize the sustainable use of land that we dedicate to agriculture (e.g., eating low on the food chain, intercropping to replenish soil, three-dimensional farming), move away from any use of wild caught food at scale (including fishing), and employ food production technologies as they become more energetically, monetarily, and environmentally effective than current practices.

1.5 Closing Remarks

Humanity uses nearly all suitable agricultural land, and has greatly impacted biodiversity while converting them (Martenson 2011; Ritchie and Roser 2013; Ritchie 2017, 2019). Natural lands must be protected to allow our relatives in the tree of life the space to survive. To feed humanity, this means that agricultural efficiency needs to increase tremendously while converting virtually no more land to agriculture. Even plant-based agriculture requires sustainable transformation. This includes implementing polycultures over monocultures, hydroponics and aquaponics powered by alternative energy, improved irrigation methods, the conservation of natural habitats, and the overall lessening of environmental impacts. If we can execute on this, then even plants and soil microbes will have healthier lives.

Further, suppose we can transform plant agriculture and pair it with alternative food production technologies powered by clean energy at scale. In that case, we have a shot at sustainably producing food for 10 billion people, for at least awhile. Yet exponential population growth cannot persist; we would need to grow more food every year. As discussed above, a population at 10 billion is not sustainable if we raised everyone's standard of living and consumption to levels currently present in developed countries such as the United States. Thus, unless we can continue changing human carrying capacity, the global population will need to reverse its current growth, and trend downward (Hall and Day 2009). Promisingly, data and modeling suggest precisely this kind of trend, with the global population peaking in 2064 and declining into 2100 (Vollset et al. 2020).

Our current situation arose from the self-centered actions that underlie our behavior. It would be wise to respect the proper place of other organisms in the environment that we all share. Transitioning from selfish thinking will require us to see that we are one lineage among millions in an interdependent tree of life. We are not superior to other organisms nor to the environments that we inhabit. We are a subset of nature, reliant upon its resources, and our livelihood depends upon accepting this. With a targeted strategy, we can divert and correct our path. We live amid a human behavior problem, not a human technology problem. Humanity currently possesses the tools to thrive sustainably on the earth while venturing into the cosmos. Within a reasonably short timeline, we need incentives and consistent policies to make this happen. These actions are necessary to prevent the negative feedbacks of our current behavior from catching up with us (Turner 2014; Jackson 2016; Foxon 2017; van den Bergh 2017; Hausfather and Peters 2020).

In all honesty, it is not clear if *Homo sapiens* will make the necessary transitions; we have been selfish throughout our short history. But if we can accomplish them, we will find ourselves in a place where we can live sustainably alongside nature while deploying sophisticated tools to support our unique phenotype. It does not make us less special to exist thoughtfully, with foresight for our future and consideration for our family (the rest of life on Earth). On the contrary, owning our shortcomings will allow us to overcome our predicaments. At that point, embracing humility and leaving speciesism behind will make us far more precious than our fragile exceptionalism has ever prescribed.

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Chapter 2
Race and Human Genomic Variation

Rasmus Grønfeldt Winther

Abstract How much do different groups of humans differ genetically? Starting from a thought experiment, this chapter shows that we differ less than we might think—and that, in a sense, *we are all Africans*. I draw on several key findings: that compared to many other species, *Homo sapiens* has relatively little genomic variation; that of all continental regions, African genomic variation is the richest and most encompassing; that population-level genetic variation decreases with distance from Africa; and that most genomic variation is found within local human populations (with only about 7% or so found across continental groups). This is not to deny that there are—small but somewhat systematic—group-level differences, but it is also important to recognize that these should not matter ethically or politically.

2.1 A Thought Experiment[1]

A few months after your intergalactic expedition left Earth, you arrive in a far-off world.[2] Departing your ship, you come upon some of the planet's inhabitants. They all seem to look the same. They are all more-or-less one meter tall and have the same muscular body and rounded facial features. You know that people sometimes say that other groups of people "all look the same," but in this case it seems nearly true: finding a distinguishing mark on any one of them is a challenge.

"Greetings, traveler," you hear through a universal translation device held up to the mouth of a single inhabitant who has emerged to meet you on the rock where you stand. "Please be at ease." You are told that every person on the planet looks the same; your greeter is no exception. You learn that centuries ago there was a Great

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[1] Parts of this book chapter were adapted from chapters 6 and 9 of Winther (2022a).

[2] I first presented this thought experiment in Winther (2018). This work was completed in 2015.

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Tragedy brought on by ethnic conflict including a calamitous civil war. Committed to preventing further destruction, the survivors agreed that for the rest of time they would engage in random breeding to avoid ethnic strife.

Call this Planet Unity.

Now, let's imagine a different scenario, perhaps a little more familiar: Imagine the Galápagos Islands, the natural experimental laboratory where Darwin studied evolution, with their wide variety and number of finch and tortoise species. Let's in our minds populate these islands—or any analogous archipelago—with identical small populations of early humans. Let's then add a few more dozen islands that are larger, mutually unreachable, and have distinct environments: Some are relatively cool and rainy, while others are hot and arid. What happens after tens of millions of years of evolution? Will the populations become more alike, similar to Planet Unity? Just the opposite, of course: Unlike on Planet Unity, the populations on these islands have come to be quite different from each other—not just in body and behavior, but in culture, as well.

Call this Galápagos-Writ-Large.

Now the real question: are modern humans more like the inhabitants of Unity or Galápagos-Writ-Large? Where do we fall between these extremes?

When we look around us on the street or in a Zoom meeting, we can easily see differences in people's eyes, skin tone, height, and the rest. Identical twins might be a partial exception! This isn't just a point about individuals: some *groups* of people seem to share physical traits in common. And this would seem to be an argument for humans fitting the Galápagos-Writ-Large scenario.

I'm going to use this chapter to suggest the opposite: the Planet Unity scenario is a much better description of our situation. To help convince you, we'll review our best genomic evidence for the (relative) unity of the human species.

It was only in the middle of the twentieth century—long after Darwin's death—that scientists started unlocking the mysteries of genetic inheritance at the molecular level. The environment is an essential part of making you what you are, but the other side of the matter is that molecule called DNA, which encodes our genes.

A reasonable starting point for examining human diversity, then, is to ask how genes differ, if at all, between individuals and groups. How similar or dissimilar genetically is anybody from anybody else, really? Let's have a look.

The genomics of recent decades has had some surprising findings. We have learned that, compared to many other species, *Homo sapiens* has relatively little genomic variation; that of all continental regions, African genomic variation is the richest and most encompassing; that population-level genetic variation decreases with distance from Africa; and that most genomic variation is found within local human populations (with only about 7% or so found across continental groups).

What does this mean? As I will show, it means *we are all African*s. But groups also differ, and these small but somewhat systematic group-level differences explode with highly charged and controversial political and ethical debates and implications.

2.2 Relatively Little *Homo Sapiens* Intraspecies Genomic Variation

Among species for which we have good data, *Homo sapiens* has rather low average nucleotide variation. At roughly 999 base pairs out of 1000 (on average), all members of *Homo sapiens* are basically identical.[3] Given our total, haploid genome size of roughly 3 billion nucleotides, two individuals will typically and on average differ at approximately 3 million nucleotides—only a difference of about 0.1%. Our closest cousins are on either side of us in this measure, but not too far: bonobos differ by 0.076%, chimpanzees by 0.134%, and gorillas by 0.158%.[4] By contrast, the most classic model organism for genetic studies, *Drosophila* fruit flies, differ from each other by 1% on average, or about 10 times our nucleotide diversity. And maize has even more nucleotide diversity than *Drosophila*.[5]

In short, there is, according to our best genomic data, a *single overarching* human race, at least as compared to less unified species.

2.3 Out of Africa Migrations

Even so, we do differ in small ways, both at the individual level and the group level. This is what makes human evolutionary genomics so fraught and so interesting. Are there alleles associated with cancer, running speed, or intelligence, and might they be distributed unevenly across human populations? If so, what are the consequences for medicine, social policy, and our self-understanding?

It is crucial to recognize that our basic evolutionary pattern is *Out of Africa migration*. You may know the story: our species originated in Africa with a few small and highly related populations. Several times, groups left Africa, grew in size and range, and underwent evolution by natural selection, random genetic drift, and mutation. (Some migration *back* to Africa also occurred.) In this way, different human populations spanned the world, occasionally interbreeding, especially in the last tens of thousands of years.[6]

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[3] Li and Sadler (1991), Yu et al. (2002), Auton et al. (2015), Biddanda et al. (2020), Winther (2022a).

[4] Yu et al. (2004).

[5] Brown et al. (2004).

[6] For a nuanced, yet somewhat non-standard view of Out of Africa migrations, see: Templeton (1997, 1999, 2002).

2.3.1 *Of All Continental Regions, African Genomic Variation is the Richest and Most Encompassing*

African human populations are the most genetically variable in the world. African populations have roughly double the nucleotide diversity of other populations. In other words, two people whose recent ancestors are of African origin differ on average by about 1:900 nucleotides (0.11%), whereas two people whose recent ancestors are of European origin differ on average by only approximately 1:1600 (0.063%).[7] Another study found that Mandinka peoples from Mali, Guinea, and the Ivory Coast and the San peoples of South Africa harbored nucleotide diversities of 0.12% and 0.126%, respectively, while Han Chinese and Basque peoples had, respectively, 0.081% and 0.087%.[8] According to Rosenberg (2011), Africa has approximately half of the world's "private alleles"—that is, alleles at a locus unique to a geographic region.[9] Many more pieces of evidence indicate that genomic variation is generally much higher in Africa, in part due to the long periods of time of human population differentiation across the African continent. Given our Out of Africa picture, none of this is surprising.

2.3.2 *Genomic Heterozygosity of Populations Decreases with Increasing Distance from Africa, Along Human Migration Routes*

Early humans had to pass through northeastern Africa to leave it, and following this path leads to interesting insights. Genetic variation in human populations reduces in proportion to its distance from Africa, as measured along historical human migration routes. This means that the further apart two populations are along these lines, the more they differ. Here we can talk about human migration as well as *genetic* migration, or the process of gene exchange when populations mix. Genetic migration also tends to diminish along human migration routes as humans move farther from Africa.[10]

The Out of Africa migration model also aligns with the data on the decline in genomic variation as you move away from our evolutionary cradle, providing very strong evidence for a general Out-of-Africa scenario of human evolution (Fig. 2.1). This occurs because when a species migrates, relatively few individuals typically move and survive. Even fewer make it when difficult barriers such as mountains are crossed. This means two things. First, due to random genetic drift (random changes

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[7] Yu et al. (2002).

[8] Wall et al. (2008), Table 1, p. 1355; cf. Campbell and Tishkoff (2008).

[9] Rosenberg (2011), p. 667.

[10] See Fig. 1b of Ramachandran et al. (2005), 15,943; similar results are found and presented by Serre and Pääbo (2004); Lawson Handley et al. (2007).

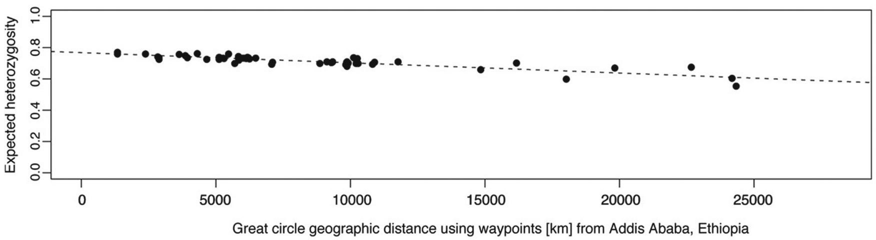

Fig. 2.1 Heterozygosity to distance from Eastern Africa global pattern. The amount of heterozygosity of each of approximately 40 worldwide populations diminishes as a function of their respective distance, along (approximate) migration routes, from Addis Ababa. (*Source* Fig. 4a, p. 15946, Support from the relationship of genetic and geographic distance in human populations for a serial founder effect originating in Africa by Ramachandran et al. (2005); https://doi.org/10.1073/pnas.0507611102 © (2005) National Academy of Sciences, U.S.A. Reprinted with permission from PNAS)

in allele frequencies across generations), small populations tend to lose genetic variation over generations (more so the smaller they are). Second, migrating natural populations experience genetic bottlenecks or a "founder effect" whenever a small group inhabits new areas.[11] Each time this happens, the founder population represents only some of the genetic variation of its parent population. These factors combine to lower the amount of genomic variation, especially outside of Africa, the home of our originary genetic variation. Interdisciplinarity and acceptance of multiple models and methods will also help paint the full picture here. For instance, archaeological and paleontological evidence can deepen and broaden our analysis.

Africa is indisputably the capital of Planet Unity—as well as the most diverse part of that planet. This is not to deny, of course, that we can see features of Galápagos-Writ-Large as a consequence of human migration and local adaptation to distinct environments.

2.3.3 Two Groundbreaking Episodes

In 1972, biologist Richard Lewontin studied the distribution of alleles across individuals from numerous groups around the globe.[12] He used genes coding for blood proteins to compare genetically different individuals within a population to individuals from other populations, both within and across continental regions. Here is his list of seven continental regions, into which he pooled populations that had been sampled and whose allele distributions (or allele frequencies) had been identified: Africans, Europeans, Asians, Southeast Asians, Indigenous Americans, Oceanians, Australian Aborigines.

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[11] Hartl and Clark (1989); Ramachandran et al. (2005); Lawson Handley et al. (2007).

[12] Lewontin (1972). For a more recent study confirming these results, see Barbujani et al. (1997). I explore Lewontin's aims and methods in Winther (2014, 2018, 2022b).

Lewontin found something astonishing: genetically, speaking, you are almost as different from someone chosen at random from your group as you are from a random person from anywhere on the globe. Our familiar racial categories are not backed up by the genetics. The human species has very little genetic variation, and it is mostly between individuals within groups—not between groups.

Nevertheless, 40 years later, a group of researchers led by Noah Rosenberg showed that even these small between-group differences provide enough information to correctly assign someone to a racial group based on knowing about 20–30 of her genes.[13]

What are we to make of this mix of results? Lewontin's work seems to suggest that races and other large human populations aren't, genetically speaking, "really real." But then how could it be possible to assign you to a race or ethnicity using just a small sample of your genes? This is not an idle question. Biologists and doctors—not to mention big pharma and insurance companies—have large stakes in understanding this puzzle.

The full answer as to why this mix of findings can co-exist would take more detail than available here. What I have elsewhere called Lewontin's "variance partitioning" and Rosenberg's "clustering analysis" are two sides of the same coin, mathematically speaking (Winther 2014). The twofold truth is this: human populations are similar in allele frequencies at many genes—but whenever we *aggregate* information about small differences across two populations, we can use this information to cluster and classify individuals into populations. Knowing an individual's multilocus genotype provides just this information. Although some refer to "Lewontin's Fallacy," I see no fallacy here: Lewontin and Rosenberg were interested in two different sets of questions and methods.

Recall our thought experiment: Planet Unity and Galápagos-Writ-Large are extremes on a spectrum. Yet, in general and on average, our species fits the Planet Unity model surprisingly well. This makes sense in light of Lewontin's results. And, in at least some places on Earth—especially big multicultural cities—our children are becoming even more Unity-like, both genetically and culturally. We see Galápagos-Writ-Large properties when we zoom in to a finer grain to explore specific genes or small populations. Admittedly, for some genes there are very large frequency differences in different parts of the world. This shows the validity of Rosenberg and colleagues' results.

2.4 Is Race Biologically Real?

Some claim that our best science indicates that human races are biologically *real* entities (e.g., Robin Andreasen, Charles Murray, Neven Sesardić, Quayshawn Spencer[14]). According to this view of *racial realism*, racial groups are clearly genetically differentiated. I believe that our best genomics obviously undercuts such a view.

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[13] Rosenberg et al. (2002). See also Rosenberg (2018).

[14] Andreasen (2000, 2007), Herrnstein and Murray (1995), Murray (2020), Sesardić (2010, 2013), Spencer (2013, 2014, 2015, 2019).

A subset of racial realists—call them "hereditarians"—argue further that the existence of biological populations explains and justifies certain social inequalities (e.g., Herrnstein and Murray 1995; Murray 2020). For them, multiple social and political inequalities, both within and between nations, are due largely to hereditary differences in the (average) innate abilities of races (as this concept is usually conceived)—intelligence, for instance. This view gives us a Galápagos-Writ-Large picture of biological race. Many hereditarians stand on the political right (e.g., conservatives, libertarians).

Compare the *racial antirealism* view developed in the wake of Lewontin's (1972) paper "The Apportionment of Human Genetic Diversity" (e.g., Joshua Glasgow, Adam Hochman, Naomi Zack[15]). For the racial anti-realist, races are social fictions without a biological basis. Such a view is widespread throughout the social sciences,[16] and is widely held by those who identify with the academic left. It can be thought of as the *liberal consensus* on race. In my view, this position goes too far and is somewhat disingenuous—it simply ignores some data.

This controversy is riddled with *burden of proof arguments*: both sides like to argue that the burden lies with the other side. The left wants the right to show strong genetic evidence for specific traits, while the right wants the left to prove that no genetic explanation for between-group differences can be given.

I would suggest that our global genome leaves it open to interpretation whether we can say that racial groups exist or not. The story is complex. Interpretation differs depending on the trait—blood proteins, skin color, behaviors, etc. At any rate, our best genomic studies in the last decade have shown that racial groups aren't very strongly identifiable and don't explain very much.[17] Moreover, the Out of Africa paradigm is basically correct. Ample genomic evidence shows, beyond a doubt, that Africa is the capital of our Planet Unity (albeit the most internally diverse part). Even so, while we are all quite similar, there may be real heritable differences that could, potentially, be politically controversial, especially if they inspire public policy or medical interventions.

We should also bear in mind that the story of race, however we conceive this fraught concept and category, is not, for the most part, a genetic story. Cultural narratives, questions of identity and belonging, are central in our attempts to understand all human groups and populations, racial or otherwise. As we will see below, whether or how race is biologically real is a separate issue from whether or how it might be socially real.

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[15] Glasgow (2009), Hochman (2013, 2016), Zack (2002).

[16] For instance: Reardon (2005); Fujimura et al. (2014).

[17] For scientific and philosophical reviews of a vast literature, see, e.g., Kaplan and Winther (2014), Winther (2019).

2.5 Philosophy and Post-Racial Futures

I believe philosophical analysis of genomics of race shows that race must be characterized in both realist (social race) and antirealist (biological race) terms. (And in *conventionalist* terms for genomic race.) It all depends on which "race" you're talking about. Mills (1998) provides a useful taxonomy of views, ranging from the denial of races' existence (Glasgow 2009) to the belief in deep biological racial "essences." To me, Mills' "objective constructivism" seems the most plausible: races are socially real and are shaped by ongoing social practices. Ásta (2018) provides a similar "conferralist" framework for analyzing the social construction of race and other categories such as sex and gender. For Ásta, race is defined by a social property, namely, "social status consisting in constraints on and enablements to the individual's behavior in a context" (2018, 2). Finally, psychiatrist and philosopher Frantz Fanon illustrates the reality and consequences of social race (e.g., structural racism), in the European colonial context.[18]

Crucially, the social construction process of race is historical and contingent.[19] This means that racial categories could always be otherwise. In *When Maps Become the World,* I defended a practice of *imagining "What if…?"*:

> In posing this most capacious question, philosophy opens up a space for memories, feelings, hopes, and imagination. When we ask "What if …?," we swap one set of assumptions for another and follow the world-making consequences of each, whether in the future or in potential existence more generally. Perhaps this is a kind of future-oriented pluralistic ontologizing. … What if social relations were structured with institutions, values, and behaviors dramatically different from those in place here, today? (Winther 2020, p. 253)

Let us here briefly address one "what if…?" possibility, that of post-racial societal futures.

A post-racial future is one in which perceived membership in a racial category is no longer associated with differential access to social goods, including dignity, trust, and opportunity. For such a future to exist, we must rip up what Charles Mills calls *the racial contract*. According to Mills, the seemingly neutral social contract theory tradition—including such philosophical luminaries as Thomas Hobbes, John Locke, Jean-Jacques Rousseau, Immanuel Kant, and John Rawls—has effectively posited a social contract between just the *people who count*, which is to say white people. Plausibly, he suggests that "White supremacy is the unnamed political system that has made the modern world what it is today." A post-racial future, then, requires struggles for recognition, power, land, and a decent standard of living—for an expanded social contract that includes all.[20]

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[18] Fanon (1952/2008, 1961/2004).

[19] Hacking (1999) provides a refreshing discussion of realism and constructivism. See also the last chapter "Map Thinking Science and Philosophy" of Winther (2020).

[20] Mills (1997), pp. 3, 1. For critical analysis of whiteness, racism, and colonialism, in addition to Fanon, see, e.g., Alcoff (2015), Coulthard (2014), Galeano (1973), and Kendi (2019). TallBear (2013) and Happe (2013) show how genomics could undermine such struggles.

Post-racial societies seem possible, and perhaps desirable. They are possible if, per some of the above discussions, each of us is willing to do the hard, critical work of simultaneously feeling a sense of belonging to our respective groups and *to all of us*, and *to all of life*. In so doing, we must also work hard not to reify and naturalize social expectations and prejudice. The result of the work need not be societies in which people no longer "see" race as a social organizing principle. For instance, social race, as I have defined it, may continue to have some relevance, but not for oppressive or negatively discriminatory purposes—perhaps only to celebrate differences, as some like to say, in culture, music, or food. Whether such a society, in the absence of stereotypical racial judgments, would be more inclined to reward people based on any number of *individual* qualities, such as work ethic or charm, is a matter for further "what if…?" discussion.[21]

Allow me to put my point starkly: *genomics simply shouldn't matter to politics.*[22] Regardless of genomic results and what they could or could not tell us, we must continue to work towards equality and dignity—also for non-human life—premised on ethics and law instead of on scientific information. Normative equality simply does not depend upon factual equality. Abstracting away from genomics, I encourage us to strengthen moral and legal frameworks to guarantee equality and protection to all.

2.6 Coda: Who Are We?

Who am I? It no longer makes sense for us to ask this question. Here, on this pale simulacrum of Planet Unity, we learn more about ourselves as individuals when we ask about the collective: Who are *we*? Who *were* we? Where did *we* come from—from what places and what ancestors? Whence humanity?

These questions include another as their flipside: Who are we not? *Homo sapiens*—that collection of us oddball apes—is not *Homo erectus* or *Homo heidelbergensis*, let alone *Australopithecus anamensis*. Nor are we Neanderthals or Denisovans, although here there is much more overlap. There are morphological and (postulated) behavioral differences between all hominin species and sub-species, including differences in average brain size, presence or absence of air sacks, and the production of particular forms of tools and weapons.

Neanderthals and Denisovans both likely emerged out of Africa. Neanderthals also evolved in Europe and western Asia, and Denisovans called eastern and southern Asia—and later Oceania—their home. There are reasonably good African *Homo* fossils before 400,000 years and after 260,000 years ago. In between lies a gap. Europe, meanwhile, has a solid fossil record for Neanderthal throughout this period (Hublin 2013).

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[21] A starting point for such a discussion might be Sandel (2020).

[22] I develop this point in detail in Rasmus Grønfeldt Winther. 2022a. *Our Genes: A Philosophical Introduction to Human Evolutionary Genomics.* Cambridge University Press.

These two subspecies or sister species of *Homo sapiens* elicit much interest. After all, most humans outside of Africa today have a few percentage of Neanderthal DNA, some of which is adaptive, for example, in fighting viruses.[23] And Oceanian peoples such as Papuans and Australian aborigines often have more than 5% Denisovan DNA.[24] Recent research finds Neanderthal DNA even in contemporary African individuals, suggesting that there were "Back to Africa" migrations, perhaps even by European *Homo sapiens*, themselves carrying Neanderthal DNA, over the last 20,000 years or so.[25]

Still, we have no evidence of Neanderthal or Denisovan mitochondrial DNA or Y-chromosomal haplotypes in any modern human population. Perhaps male fetuses with Neanderthal fathers and human mothers were inviable.[26] I leave it to the interested reader to draw out various mating combinations, in order to see that both Neanderthal mitochondrial DNA and Y-chromosomes can be lost in two generations, while autosomal DNA easily introgresses into the human genealogy.[27]

While we have a few answers, many more remain: The history of *Homo* cannot but raise questions about how to untangle our DNA, "whose" DNA it is, and why Neanderthals went extinct approximately 40,000 years ago.[28] Taking a wider view, we can ask which species—and places—gave rise to our nearest contemporary cousins: bonobos, chimpanzees, and gorillas (Fig. 2.2). Such questions bring us closer to our ancestors, inviting a sense of connection and belonging across the branches of the tree of life. Our best genomics blurs all kinds of putative boundaries, showing the deep and broad connection of all life.

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[23] E.g., Enard and Petrov (2018). The divergence between Neanderthals and modern humans, *Homo sapiens* can be estimated. Mendez et al. (2016) use Y-chromosome DNA from a Neanderthal to estimate divergence time to be around 588,000 years ago; Langergraber et al. (2012) find the temporal range for the split to be 400–800,000 years ago; Gómez-Robles (2019) uses fossil teeth, not genetics, to place the split at no less than 800,000 years ago.

[24] Many central, south, and east Asian populations, as well as Indigenous Americans, have small amounts of Denisovan DNA (Jacobs et al. 2019). Typically, because of chromosomal recombination over many generations, the regions of the Neanderthal genome interspersed in our genome are less than a hundred kilobases long (Sankararaman et al. 2014). For further reviews and citations, see also Nielsen et al. (2017), Bergström et al. (2020), and Winther (2022a), especially chapter two.

[25] Chen et al. (2020).

[26] See, e.g., Mendez et al. (2016), p. 732. Or maybe any such haplotype lineages in *Homo sapiens* died out due to selection or chance (See Prüfer et al. 2014; Nielsen et al. 2017, https://humanorigins.si.edu/evidence/genetics/ancient-dna-and-neanderthals/interbreeding).

[27] Of course, it is possible that we have yet to discover a new Neanderthal Y-chromosome or mitochondrial DNA haplotype from archaic remains, perhaps present somewhere in a human population, either already sampled or not. (On the converse point of human introgression into the Neanderthal lineage, see, e.g., Raff 2017).

[28] Chen et al. (2020); Vaesen et al. (2019).

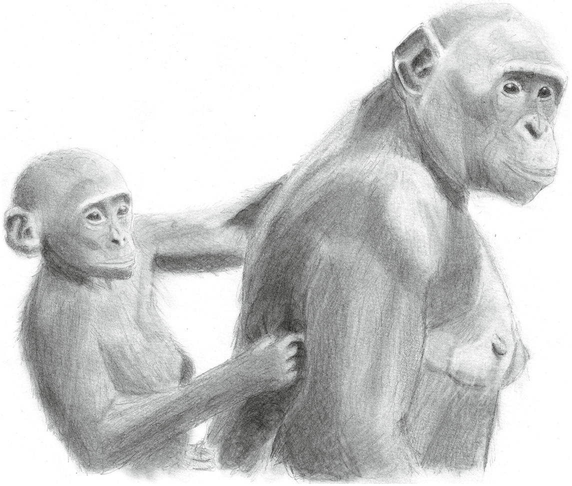

Fig. 2.2 Our cousins: Bonobos. Bonobos (*Pan paniscus*) are known for their empathy, matriarchal society, relative peacefulness, and rampant sexual activity across a range of relations (e.g., de Waal 2013, 2019). Bonobo mothers frequently permit other group members to handle their infants; 96% of these interactions were positive in one study (Klaree et al. 2018). (Illustrated by Daphné Damoiseau-Malraux. © 2020 Rasmus Grønfeldt Winther)

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Chapter 3
Science Without Species: Doing Science with Tree-Thinking

Nicholas J. Matzke

Abstract The focus of this volume is speciesism. While the concepts of species and speciation remain the focus of a great deal of research, it is worth exploring how in recent decades evolutionary biology has, in several ways, moved away from species as the key unit of analysis of biological questions. I begin by outlining how phylogenetic comparative methods have become essential methodological tools in statistical analyses of relationships between traits. Species are not statistically independent observations, because the reality is that they are related, genetically and statistically, on a phylogenetic tree. Phylogeny also plays a key role in modern analyses of spatial patterns in biodiversity, and in fact relying on phylogenetic biodiversity measures can avoid a number of problems created by attempting to impose a uniform species rank across different continents and clades. Similarly, a major challenge in modern studies of diversification and extinction concerns the units of analysis and how they are defined and recognized. Both "genus" and "species" are human-defined ranks imposed on the phylogenetic tree. The phylogenetic tree is the more fundamental reality that is produced by the macroevolutionary process, and it could include every level of gradation of genetic and morphological divergence. Once ranks are imposed upon it, a variety of methodological problems are created as scientists attempt to make these ranks standardized and comparable across different datasets and timescales. I outline how phylogenetic thinking might help provide a solution. I conclude with other examples where cutting-edge science is done with phylogenies without much need of the "species" rank—for example, in the battle against Covid-19.

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3.1 From Comparative Methods to Phylogenetic Comparative Methods

Common research questions in ecology and evolution are about the relationship between different traits, observed across many extant taxa. Is brain size related to body size in vertebrates? Is height related to seed dispersal distance in plants? Is genome size related to organism size in eukaryotes? Such questions are always aimed at eventually trying to tease out cause and effect, but a crucial preliminary scientific step is to determine whether or not two traits are even correlated.

In the “olden days” of biology—by which I mean before the 1980s, which is of course not that long ago—the standard procedure in testing for correlation would simply be to measure the trait values across many species, plot the data, fit a linear regression, and check if the slope of the line was significantly different from 0.

A flaw in this work was exposed in a famous paper by Felsenstein (1985). He noted that, if species shared common ancestry, and thus had shared phylogenetic history, then different species will not be statistically independent samples. Instead, species that are more closely related will tend to have more similar traits. He illustrated this with an imaginary “worst-case scenario” (Fig. 3.1).

In Fig. 3.1 (middle), 20 species in Clade A are equally related to each other, as are another 20 species in Clade B. However, the two sister clades are separated by a long period of independent evolution, indicated by long branches. Imagine we have measured two continuous traits, for example, tree height and seed mass. If we imagine a simple (if no doubt unrealistic) model for evolutionary change in these traits, wherein trait values randomly wander without any directional trend, but with the expected amount of wandering increasing with time, then a lot of evolutionary change can accumulate along those long branches. Even under this simple model, it is likely that the common ancestor of Clade A will have values for Traits #1 and #2 substantially different than the common ancestor of Clade B.

As Node A diversifies into Clade A, and Node B diversifies into Clade B, the traits of each descendant species randomly wander away from their common ancestral

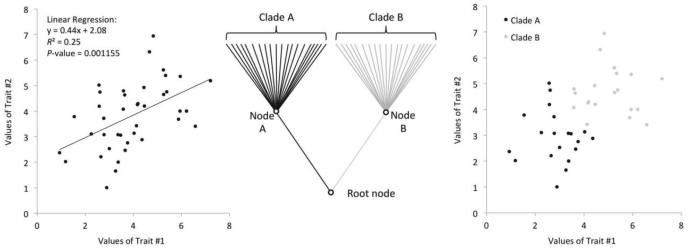

Fig. 3.1 Felsenstein’s “worst case scenario” where an apparently strong correlation between two traits across species (left) is due to two sister clades (middle) simply having different averages in the two traits (right). Such spurious correlations are easily generated by simulating the gradual evolution of 2 independent continuous traits on this tree structure. (After Figures 5 and 7 of Felsenstein 1985)

values. When the resulting data are plotted (Fig. 3.1, left), it appears that Trait #1 and #2 are strongly correlated, with a positive slope of 0.44, an R^2 suggesting that Trait #1 explains 25% of the variation in Trait #2, and P-value of 0.001155, reassuringly well below the standard $P < 0.05$ cutoff for statistical significance. Excited biologists could publish this correlation and speculate on causal relationships.

Unfortunately, as Felsenstein pointed out, the whole analysis is spurious, because the entire signal of relationship is coming from the different mean values of Traits #1 and #2 in the two clades, and because Clades A and B inherited different ancestral starting values from their respective ancestors at Node A and Node B. Instead of having a sample size of $n = 40$ independent species supporting a relationship between the two traits, in this imaginary study, the real sample size is really just $n = 2$ sister clades with different means. Of course, a relationship can be postulated based on two points, but $n = 2$ is not an acceptable sample size—a straight line can always be drawn between two points!

The problem that Felsenstein identified is just an evolutionary special case of the common problem of statistical non-independence in data. Classic statistical methods and their results (such as estimates of the slope of a relationship, or the P-value) assume that data within a group are "IID"—independent and identically distributed. In other words, they assume that each of the data points is an independent sample from the same underlying population or process. However, if the underlying process created correlational structure in the data, and this structure is ignored in the statistical models used, then the statistical results can be badly misleading.

The evolutionary process of descent with modification is just such a process, and the "groups within groups" structure produced by a phylogenetic tree (see the concept "clade" in Table 1.1 of Chap. 1 in this volume) means that lineages' traits will often share a pattern of similarity that mirrors the closeness of the species on the phylogeny. While this pattern of correlations can itself be useful—notably, it can provide evidence of the phylogenetic tree—it is a major hindrance when attempting to determine if traits are correlated for some other, non-phylogenetic reason.

Fortunately, Felsenstein's paper did more than just point out the problem: it also pointed out a theoretical solution. Felsenstein noticed that, while the raw measurements of traits across species will be strongly correlated because of shared evolutionary history, the *differences* between sister clades will be statistically independent because they represent the changes in traits that have accumulated since the clades diverged from a common ancestor. This applies whether the clades are "small" (equivalent to what were traditionally termed species), or "large" (where a clade includes multiple populations/"species").

Felsenstein's method is known as Phylogenetic Independent Contrasts (PICs). While the details of the method involve some math and assumptions (Huey et al. 2019) about the evolutionary process, the method is now implemented in open-source programs, for example in the free computer language R (Paradis 2012). It can be run in seconds, given a data table and an estimate of the phylogeny.

An empirical example is given below. A common, but flawed, intuition is that genome size is tied in some way to organismal complexity, with the "better" or bigger organisms having bigger genomes. After all, bacteria have small genomes

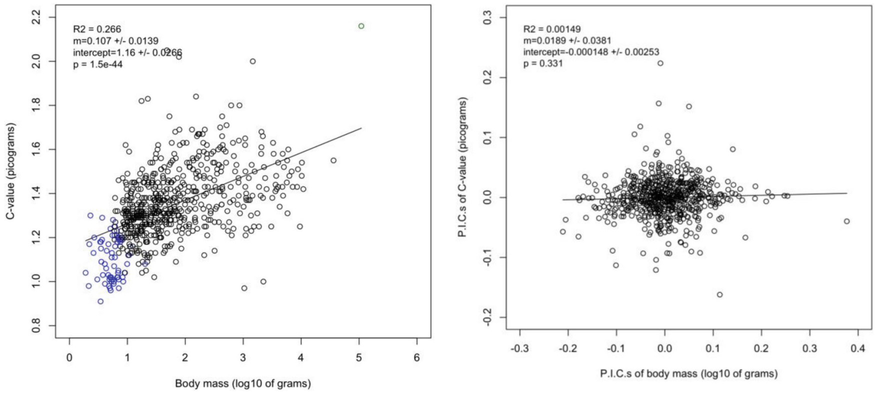

Fig. 3.2 Body mass plotted against genome size, in birds. The raw data seems to show that smaller birds have smaller genomes (left), but this relationship disappears when the autocorrelation due to shared ancestry is removed through Felsenstein's Phylogenetic Independent Contrasts (P.I.C.s) technique (right)

(often about 1 million DNA "letters," or bases), and complex organisms like us have large genomes (humans have over 6 billion bases of DNA in our diploid genomes). What happens when we test this hypothesis?

Data to address these questions are now available in various published databases (Gregory et al. 2007; Jones et al. 2009; Myhrvold et al. 2015; Gregory 2021). Birds are an excellent instructive example. Figure 3.2 was created by plotting the logarithm of body mass (x-axis) against genome size (y-axis), represented by the "C-value," a term for a physical measurement of the mass of the genome in picograms (genomic size has been measurable since the 1950s using techniques from cell biology long before genome sequencing was available).

If we look at the regression in Fig. 3.2 (left), it appears that despite substantial scatter, there is good evidence of a positive relationship. The slope is positive, the R^2 is 0.27, and the P-value is an impressive $P = 1.5 \times 10^{-44}$. Conventionally, any P less than 0.05 would be considered a statistically significant relationship. However, when we take the *same* data and use the bird phylogeny to calculate the body mass *contrasts* and C-value *contrasts*, the regression of contrasts against each other (Fig. 3.2, right) has a slope indistinguishable from 0, with a nonsignificant P-value of 0.33.

It turns out that a lot of what is driving the apparent relationship in Fig. 3.2a is the fact that hummingbirds, indicated by the blue circles, have both tiny body masses and slightly smaller genomes than other birds. However, all hummingbirds share these two traits, which were presumably already present in a common ancestor, so in actuality, this only provides one instance where body size and genome size appear to have shifted together. When this contrast is included with all of the other contrasts across the bird tree of life, no overall relationship is supported.

It is important to note that the PICs method does not always destroy apparent relationships. While relationships between genome size and complexity or body size

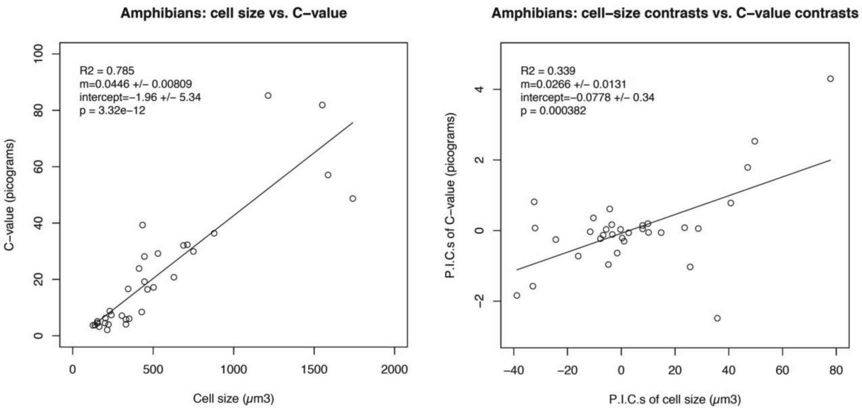

Fig. 3.3 Amphibians show a strong relationship between red blood cell volume and genome size. This relationship is strong both in the raw data (left) and in the phylogenetic independent contrasts (right)

are often not supported in analyses of multicellular clades, some clades show a strong relationship between genome size and the size of their red blood cells (Fig. 3.3). In this case, the apparent relationship in the raw traits is confirmed in the regression of PICs.

Using our random-wandering model for continuous traits evolution, we can estimate, very approximately, the most probable ancestral values of cell size and genome size. These ancestral state estimates can be mapped onto the amphibian phylogeny (Fig. 3.4). Doing so shows why the correlation between the two traits is not merely a product of phylogenetic structure: across the amphibian tree, increases in cell size co-occur with increases in genome size, and these coincident events occur many times across the tree.

When Felsenstein proposed PICs in 1985, the peer-reviewers were skeptical that the technique would be useful because good estimates of phylogeny were usually not available (Huey et al. 2019). However, with advances in DNA sequencing technology, and computer programs to estimate phylogenies from DNA (several of them developed by Felsenstein), phylogenies became ubiquitous in the 1990s. Nowadays, it is virtually impossible to publish a paper in comparative biology without using Felsenstein's Phylogenetic Independent Contrasts, or some more advanced method.

The PICs method has now been around long enough that it is considered conventional. However, it is already clear that more sophisticated methods will come to dominate the science of comparative biology in the future (Uyeda et al. 2018). These more complex methods also rely on phylogeny to account for similarities due to shared evolutionary history.

This vignette is relevant to speciesism because it shows that the shift from species-based thinking to phylogeny-based thinking impacts our general scientific and philosophical understanding of the world and the basic statistical methods that scientists use to test hypotheses. It is worth noting that PICs and related tools can be used to test

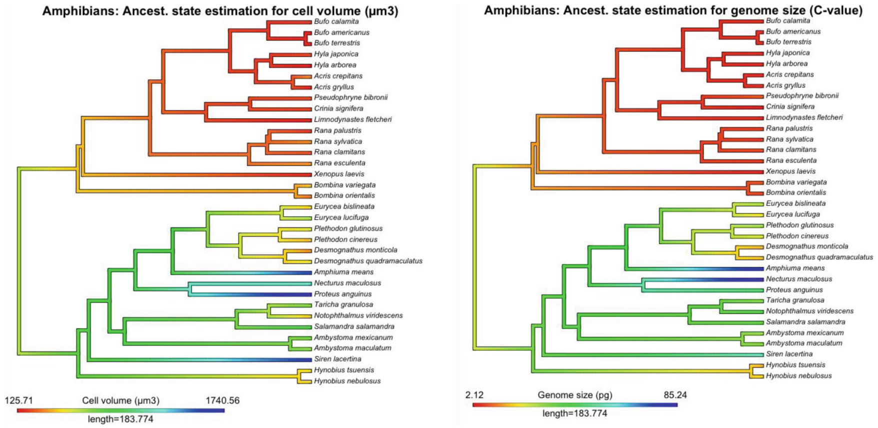

Fig. 3.4 Inferred evolution of red blood cell size (left) and genome size (right) in amphibians, under a simple model known as Brownian motion. Mapping traits onto the amphibian tree of life shows that the correlation between traits does not always result from the bias of phylogenetic relationships. In this case, increases in cell size co-occur with increases in genome size, and these coincident events occur many times across the tree. See the colorized legend illustrating how cooler colors (cell volume, left—vs.—genome size, right) arose multiple times in separate cases

hypotheses whether or not the "Operational Taxonomic Units" at the tips of the tree are considered species, or some other level of lineage. Populations, virus strains, and languages can all be analyzed phylogenetically since they originate through "descent with modification" involving the copying of information and stepwise changes that are themselves copied. Even anti-evolution legislative proposals have been analyzed phylogenetically! (Matzke 2016).

3.2 Biodiversity in Space: Spatial Phylogenetics

Phylogeny-based thinking has also had a major impact in another subfield of ecology and evolution: measuring biodiversity and mapping how it changes in time and space. Traditionally, the dominant measure of "biodiversity" has been simple species diversity: the number of species counted in any particular sampling unit, such as a geographical region or a geological time-bin.

However, knowledge of evolutionary trees means we know that not all "species" are equally distinct. Some species represent very young lineages that have diverged from their still-extant relatives in an evolutionarily short period of time, perhaps hundreds of thousands or even just thousands of years. Other species represent the last surviving members of lineages that have existed for hundreds of millions of years.

Both cases are important and worth preserving, but many people have long felt there is something significant about the last surviving members of ancient lineages.

Although the term “living fossil” has various problems (Casane and Laurenti 2013), it does capture the astounding fact that some lineages (e.g., the living tuatara, the platypus, southern conifers like the kauri and Wollemi Pine, and the ginkgo), would only be known from fossils except for the survival of these species, often in relatively isolated geographies or habitats.

While this “feeling” of significance is worthwhile, scientists like to quantify, and the advent of widespread phylogenies has enabled scientists to apply numbers that capture the uniqueness of extant lineages (Rosauer et al. 2009; Mishler et al. 2014). The measurable quantity is simply: how much of the living Tree of Life would be lost if a particular species (or some other clade) went extinct? In the case of New Zealand’s tuatara, something like 250 million years of evolutionary history would be lost. The extinction of humans, in contrast, would result in only about 6 million years lost from the Tree of Life, assuming our closest relatives, the chimpanzees, survived. The extinction of the domestic horse might only cause the loss of about 1 million years of history, due to the existence of close relatives (donkey and zebra; Lippold et al. 2011).

Merely having this measurement does not itself resolve moral or policy questions about where to put conservation efforts and money; these are questions for conservation biology and policymakers. However, measuring the “phylogenetic diversity” or phylodiversity (Kling et al. 2018) represented in a region may be a more stable and useful measurement of the biodiversity of a unit than the species count, which can shift as taxonomic conventions and technology change. Crucially, such measures can be mapped, forming the basis of the nascent science of spatial phylogenetics (see Allen and Mishler, Chap. 8, this volume).

Maps of phylodiversity are useful scientifically because they provide a historical dimension for studying the processes that produced and maintained extant biodiversity and its distribution. Interestingly, some regions of the globe have relatively more neoendemics (endemic lineages that originated recently) and other regions have relatively more paleoendemics (endemic lineages that are the last representatives of ancient groups and persisted or accumulated in a particular region). While the mapping of phylogenetic diversity and neo/paleoendemism is well advanced, attempting to fit models to the observed patterns is still at an early stage, albeit with a promising start.

3.3 Studying Biodiversity in Time: The Challenges Imposed by Ranks

In one sense, paleontology has long done science at something other than the species level. Due to the incompleteness of the fossil record, studying diversification and extinction with only species counts is often statistically dubious. The number of fossil species known in particular regions and time-bins can depend heavily on the amount of fossil-bearing rocks of the right location and age, the quality of preservation, taxonomic opinion, and even paleontological interest—the number of paleontologists available for a particular clade, region, and time, and the amount of effort they spend discovering and describing fossils (Valentine 1985).

For these reasons, it is common place for paleontologists to study macroevolution using coarser measures of biodiversity, typically higher Linnaean ranks, such as the number of genera or families. While the practice of counting Linnaean taxa—which are fairly subjective groupings—has various plausible critiques (de Queiroz and Gauthier 1994; Hendricks et al. 2014), it remains true that major features of the history of life (e.g., the five great mass extinctions [Barnosky et al. 2011]), were discovered by counting Linnaean ranks. Such studies would probably have been difficult or impossible if species-level data had been insisted upon. "Species-level" macroevolutionary studies of the fossil record remain challenging today, and species numbers are often back-calculated from higher level ranks.

Perhaps stemming from these successes of a rank-based approach, paleobiology has, ironically, been one of the slowest areas to adopt the phylogenetic approach that has swept through other fields of biology. There are several major challenges here.

First, fossils do not retain DNA. Subfossils (younger organic remains of organisms, such as Neandertal teeth or frozen mammoths) are an exception, but they are a minor one since DNA degrades over time. Even under the best conditions (frozen), a recoverable DNA sequence seems to have a limit of about 1 million years. Without DNA, phylogenies must be estimated from morphological characteristics. While DNA phylogenies are routinely built from thousands or millions of DNA characters, vertebrate fossils typically only have a few hundred characteristics that can be used (scored) as phylogenetic data. Other fossils, such as clams, may have only a few dozen scoreable characteristics.

A second challenge is the phylogenetic methods available for fossil data. Scientists want a time-scaled phylogeny that includes fossils, but this requires probabilistic models of the data. Modeling DNA datasets is aided by the large amount of DNA data available and the simple manner in which DNA is assumed to evolve. Thus, DNA models have been developed continuously since the 1980s. In contrast, morphological data have only received serious modeling attention in the last half-decade (Matzke and Irmis 2018), and the models available are essentially modifications of the DNA models, which is suspect given the greater complexity of morphological evolution. These models seem to work well enough, at least with reasonably large and semi-complete datasets (Matzke and Wright 2016). However, many fossil datasets are small and incomplete. Models are imaginable where fossil sampling completeness varies strongly among regions, ecologies, and time-bins, but such models will require the combined expertise of computational biologists, paleontologists, biogeographers, and experts in the evolution of development ("evo-devo") to develop successfully.

A third challenge concerns the different nature of Operational Taxonomic Units (OTUs, the tips of the branches) in living and fossil datasets. Due to the limitations in the fossil record and in the information that fossils retain, it is quite likely that biologists will be able to distinguish OTUs much more finely for living organisms than for fossil ones. Cryptic "species," for example, are typically only recognized based on molecular data and would be indistinguishable in the fossil record. Similarly, species that are very similar skeletally, but distinguished by different coloration patterns, vocalizations, breeding times, etc., will be indistinguishable in the fossil record. For these and other reasons, there can be a major mismatch between the OTUs available in the recent and those identifiable even with a very complete fossil record.

Finally, apart from the above challenges, a fourth difficulty remains: are the OTUs that are measured in the present "the same kind" of entity as the lineages when a phylogeny goes back in time? It is entirely possible, even likely, they are not. The former are synchronic while the latter are diachronic (Mishler and Wilkens 2018, Fig. 3.1; see also Table 1 in Swartz and Mishler, Chap. 1 in this volume). What I am proposing is something like the process of coalescence that is well-known to population geneticists. Coalescence refers to how gene variants within populations mutate and replace each other rather rapidly on a timescale of millions of years, even with natural selection occurring. For example, all extant human mitochondrial DNA traces to a common ancestor only 250,000 years ago, meaning that in 0.25 million years, the mtDNA of "mitochondrial Eve" took over the entire human population. This process is continually ongoing throughout the genome of sexual species.

With OTUs that we can distinguish in the present (e.g., populations, subspecies, or closely related species), there may be a somewhat analogous process operating. It could be that recently diverged populations are evolutionarily ephemeral, with most of them getting wiped out rapidly by climate shifts, stochastic disasters (major floods or fires, diseases, etc.), competition from nearby relatives (Gutiérrez et al. 2007), etc. Methods that try to learn about the rates of diversification from dated phylogenies typically assume that all the branches of the tree, from the root to the tips, represent the same kind of entity such that the phylogeny could be sampled at any time-point. But what if the tips of the phylogeny consist of ephemeral clades with short evolutionary lifespans, and the deeper branches of the tree represent more stable entities, for example, a group of populations that occupy a distinct region or ecological niche? In this situation, it would be difficult to make accurate inferences about the rates of diversification, let alone extinction (Marshall 2017). The divergence events detectable deep in the tree would represent relatively rare events (e.g., successful colonization of new areas or niches), but the divergence events near the tips would mostly represent a more common and trivial process of partial genetic differentiation of populations on a landscape.

Biologists are hard at work attempting to address these issues. One avenue to try and address the issue of alleged "incomplete speciation" (we should note in passing the almost teleological speciesism assumption here) is to develop models that include heterogeneity in the diversification process. For example, so-called "extended speciation" models postulate not only rates of lineage splitting and extinction, but also a process of "speciation completion," which assigns a rate at which an already-separated population becomes a "fully distinct species" (Sukumaran et al. 2021). Given this postulate, the speciation-completion process can be incorporated into a large joint model that delineates species and estimates the number of distinct species.

3.3.1 A Rank-Free Suggestion for Studying Biodiversity in Time

Even assuming terminal clades have been successfully identified in the present, the major challenge of a major mismatch between living OTUs and fossil OTUs remains. One "solution" is to essentially declare them incommensurate. In this case, inferences based on phylogenies of living species would provide information about speciation rates at the tips of a tree, fairly reliable signatures of processes just below the tips (Upham et al. 2021), and the fossil record would be used for information about larger clades in the deeper evolutionary past.

I suggest that the "science without species" paradigm might provide an alternative that is worth exploring when studying biodiversity over time. DNA-based phylogenetics can provide a more finely-resolved tree than can the fossil record, but the fossil record provides information about extinct lineages that is (at best) very difficult to recover from DNA phylogenies. How can these two data sources be combined, rather than merely analyzed separately and compared?

There is room for many approaches here, but one that seems underexplored is a multiscale analysis of phylogenetic diversity. By this I mean that any phylogenetic timetree can be queried not only for the number of lineages, N, recorded at any timepoint t—let's call this N_{t+0}—but also for the number of lineages *of a given age* recorded at each timepoint. For example, the number of lineages recorded 1 million years before any given timepoint t would be N_{t+1}, and the number of lineages recorded 5 million years before any given timepoint t would be N_{t+5}. The advantage of this approach is that a metric like N_{t+5} is likely to be much more robust to the above-identified vagaries of fossil sampling, such as fossil species and genus diagnosis, and species delimitation identified above. A combined DNA + fossils phylogeny might well serve as the basis for providing good inference of the rates of processes affecting N_{t+5} through time, however difficult it might be to study N_{t+0} through time.

But there is no need to pick any single time-resolution to study diversification. This would just impose another rank as the one true unit of analysis. Given a phylogeny that includes thorough fossil sampling, the metric is easily calculated at various time-depths. Instead of just relying on a Lineages-through-time (LTT) plot to represent diversification history, LTT curves calculated at a series of time-depths, for example, N_{t+0} through $N_{t+20,}$ could be calculated. Evolutionary models appropriate to shallow-time or deeper-time processes could then be fit, with the expectation that the latter are likely to be easier for time periods before the Recent.

3.4 More Science Without Species

I have outlined above where the phylogenetics revolution in biology can deemphasize, and perhaps totally dispense with the rank of "species" as the key unit of analysis in comparative biology, biogeography, and macroevolutionary diversification.

However, there are other major research topics where the phylogenetics revolution has already thoroughly supplanted the species paradigm.

3.4.1 Gene Trees

In “first-generation” phylogenetics, roughly into the early 2000s, it was common for biologists to assume that if they sequenced three genes from each of 20 species, they should expect that all of those gene trees would be congruent—meaning that the phylogeny of each gene should show the same relationships between species. Disagreement between gene trees was annoying and was termed “incongruence.” Generally, the “solution” was to combine all the gene sequences into one large alignment and estimate the phylogeny from the combined dataset, providing a best-estimate phylogeny supported by the majority of data. Unresolved parts of the tree could, hopefully, be resolved by sequencing more genes and adding them into the analysis.

While this “concatenation” procedure was not crazy (and yielded reasonably accurate phylogenies), it left out the fact that genes evolve in populations, and recombine in each generation as chromosome segments are shuffled around. As a result, population genetics *predicts* that many individual genes will have phylogenies slightly different from the overall phylogenetic divergence history of the population, particularly if population sizes are large and the time between population-divergence events is small (Ashman et al. 2018). New phylogenetic methods jointly estimate individual gene phylogenies along with the population phylogeny.

3.4.2 Virus Trees

Viruses have never fit well into the “species” paradigm—it is even debated whether viruses are technically “alive.” Whatever the case, it is clear that viruses evolve through descent with modification, and thus phylogenies can be good models to represent their evolutionary history. Viral phylogenetics is a fascinating example showing the benefits of “pure science,” basic research that is done to advance scientific understanding rather than practical application, yet which nonetheless turns out to have tremendous application. The field of phylogenetics was largely developed by morphological taxonomists and molecular biologists who wanted to better understand the evolutionary history of their study organisms. One particularly important figure, Willi Hennig, is considered the father of phylogenetic systematics, but his taxonomic expertise was on Micropezidae, a family of flies. However, from humble roots, phylogenetics has grown to be a crucial tool in acute life-and-death situations, namely, viral outbreaks. I used to make this point at meetings by citing a *Science* paper tracing the 2014 Ebola Virus Disease (EVD) outbreak in West Africa (Gire et al. 2014), which concludes with: “Tragically, five co-authors, who contributed greatly to public health and research efforts in Sierra Leone, contracted EVD and lost their battle with the disease before this manuscript could be published."

In the 2020s, of course, what was previously shocking now seems almost quaint, with the entire globe battling SARS-CoV-2, currently credited with over 6 million deaths, which is certainly a vast undercount. Every day, scientists are sequencing new variants of our opponent and adding them to an international phylogenetic database so we can watch when and where new strains emerge and spread (https://nextstrain.org/ncov/gisaid/global). Phylogenetics supplies the structure upon which we base the namings of new strains ("Alpha," "Delta," etc.). In the case of New Zealand, where I reside, for the first several waves of infection, every new COVID case was sequenced and added to a comprehensive phylogeny used to track viral incursions in real-time (Douglas et al. 2021; Geoghegan et al. 2021; see also https://nextstrain.org/community/narratives/ESR-NZ/ GenomicsNarrativeSARSCoV2/aotearoa-border-incursions). It was common to hear the nation's Director-General of Health, Ashley Bloomfield, discuss phylogenies and clades before the national media in the daily 1 pm COVID briefing.

3.5 Conclusion

In summary, we have seen that a major challenge in modern studies of diversification and extinction concerns the units of analysis and how they are defined and recognized. Both "genus" and "species" are human-defined ranks imposed on the phylogenetic tree. The phylogenetic tree is the more fundamental reality that is produced by the macroevolutionary process, and it could include every level of gradation of genetic and morphological divergence. Once ranks are imposed upon it, a variety of methodological problems are created as scientists attempt to make these ranks standardized and comparable across different datasets and timescales.

The only figure that Darwin put in his 1859 *Origin of Species* was a (hypothetical) phylogenetic tree. While his title put focus on how the entities people call species originated, and this concern dominated evolutionary science for many decades, a careful reading of the *Origin* indicates that the whole point was to undermine the permanency of species in favor of a phylogenetic view. We can trace a clear path from his phylogenetic speculations in 1859 to the phylogenetics revolution of recent decades (Fig. 3.5) and the real-time global tracking of deadly pathogens today. While showing the impermanence of species was one of Darwin's major revolutionary advances, it may be that phylogenetic thinking, which in time may allow "science without species," could, in the end be the bigger of the two revolutions.

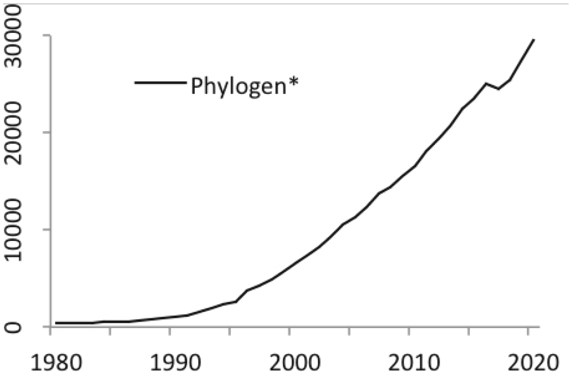

Fig. 3.5 Number of scientific publications using the word "phylogeny" and cognates, 1980–2020, according to the Scopus database (searched August 2021). By 2013, phylogenetics articles accounted for ~ 1% of all published science (David Hills, personal communication), and publication counts have grown 50% in the following 7 years

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Part II

Culture and History

Chapter 4

‘Detritus of a Coming World’: The Colonization of Islands as Microcosms for Human Impacts on an Interplanetary Scale

Scott M. Fitzpatrick

Abstract The ability of humans to colonize islands in the ancient past required centuries of innovation in boat construction and the development of increasingly sophisticated seafaring technologies and wayfinding strategies. Nowhere is this more evident than in the vast expanse of the Pacific, where around 3000 years ago, Micronesian and Polynesian voyagers colonized what were arguably the most remote and difficult places to reach on Earth. Because the biota on these islands evolved for thousands, or even millions of years, high rates of endemism in these environments also made them ecologically fragile. The first arrival of *Homo sapiens*—the ultimate adaptive omnivore—caused a wide variety of impacts that were amplified by an order of magnitude with Euro-American incursion. In this sense, as aquatically bounded places, islands serve as model systems and microcosms for how humans have affected the earth’s biosphere in the modern age. In this chapter, I document how the first island colonizers caused certain levels of ecological destruction, using Hawaiian and New Zealand birds as primary case studies. However, I take this concept further, suggesting that the processes involved in the prehistoric colonization and settlement of islands is also a corollary for how we can view the earth and future efforts to colonize other planets. Humanity is at a global tipping point, with unsustainably high human population impacts, habitat destruction, climate change, and recent pandemics. As the possibility of extraplanetary migration becomes an increasing reality—perhaps a necessity to ensure our survival—what lessons can be learned from the anthropological and archaeological study of islands as we seek new lives beyond *terra firma*? What are the possible consequences for our lineage and extraterrestrial life on this planet and beyond?

The title derives from a quote in the movie *Tenant* (2020) in which one of the characters describes remnants of complex objects from the future as “detritus of a coming war.”

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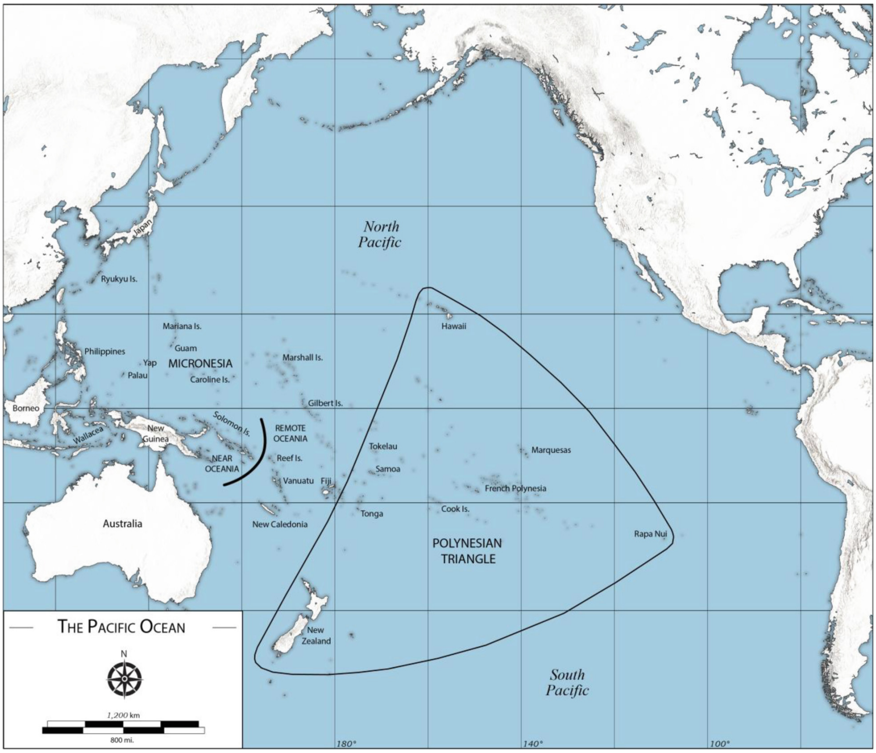

Fig. 4.1 Map of the Pacific showing separation of near and remote Oceania, the Polynesian triangle, and major islands and archipelagos

4.1 Introduction

During the late Holocene, between 3300 and 800 years ago, humans underwent the most rapid and extensive migrations in history. They colonized Micronesia and Polynesia, which comprise much of the Pacific and what is known today as Remote Oceania[1] (Fig. 4.1). After honing their skills for millennia around the hundreds of islands comprising Wallacea, the Philippines, and those surrounding New Guinea, these voyagers began colonizing the Pacific in a series of migratory movements that took them to what were arguably the most remote places on the planet. Reaching them required planning, provisions, and the ability to navigate across a seemingly boundless ocean for weeks or months using the stars and various wayfinding techniques. They took with them roots and tree crops, domesticated animals, tools made from stone and other materials, and centuries of inbuilt cultural knowledge. Combining these extraordinary efforts and carefully honed skills led Pacific Islanders to become

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[1] This is a term given to those islands in the Pacific that are not intervisible, including Micronesia, Polynesia, and parts of island Melanesia.

the first colonists to step foot on these aquatically bounded landscapes. Yet as archaeological research shows, these islands would forever be altered by the presence of *Homo sapiens*.

What were the effects of humans on pristine island environments and how can these be tracked archaeologically? How has humanity altered the composition of island biotas? Has it always been destructive? These are fundamental questions for archaeologists who work on islands and are often situated within a framework that aims to identify long-term processes that occurred before and after the arrival of humans. By integrating paleoecology, archaeology, anthropology, and more recent history, scholars have tried to identify the ecological distribution of biodiversity and how human contact may have affected these newly discovered places (Braje et al. 2017; Braje and Erlandson 2013; Erlandson and Rick 2005; Fitzpatrick and Keegan 2007; Rick et al. 2013). Knowing the timing and extent of anthropogenic effects is important for understanding how humans dealt with new environments and how we modified them to ensure long-term survival. We must also consider the impact of people (mis)managing their social affairs and resources (Kirch 2007; Leppard 2019).

In this chapter, I examine how islands can serve as model systems for examining human impacts using the Pacific as a case study. This region documents how *Homo sapiens* has overcome significant technological challenges in long-distance transport (e.g., watercraft) that enabled them to endure travel across the open-ocean and establish colonies that over time became disconnected from their homeland. However, I expand on these cases and use them as corollaries for how nations, particularly the Soviet Union/Russia, United States, and China, have put humans into space, while many others, including the European Union, Japan, and United Arab Emirates, have made continued efforts to move beyond Earth and explore the universe for signs of the universe's origins, extraterrestrial life, and extraterrestrial habitats.[2] As colonizing Mars and other planets becomes more of a reality—perhaps even an ecological necessity—what lessons can we learn from archaeology and the ancient settlement of islands to help us better understand the future?

4.2 The Pacific Diaspora

Just prior to 3000 kya (kya: thousands of years ago), seafarers in the southwest tropical Pacific began to venture from their island homes and settle others that were 100s–1000s of kilometers away. This was not the first time that humans ventured to other islands of course. Examples range from the early case of *Homo erectus* reaching the Indonesian island of Flores around 800 kya; more frequent seafaring between 60 and 10 kya when Australia, the Bismarck Archipelago, and Solomon Islands were settled (Kealy et al. 2016, 2017; Roberts et al. 2020; Shipton et al. 2020); the island of

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[2] While the number of nations with established space programs is relatively few, and those that have put humans into space is even fewer, this belies the fact that to date, astronauts/cosmonauts from 41 countries have now been to space.

Kozu off the coast of Tokyo at 20 kya and Ryukyu archipelago ca. 35 kya (Erlandson 2001); Crete, Sicily, Sardinia, Corsica, Cyprus, and Melos in the Mediterranean ca. 10 kya and 13 kya, respectively (Broodbank 2006; Dawson 2014:136–137; 173); and the Channel Islands of California ca. 13 kya (Rick et al. 2005) (see also Erlandson 2001; Fitzpatrick and Erlandson 2018). What these population movements clearly show is that humans around the world were independently inventing seaworthy craft and developing the skills to travel longer distances (between 20 and 180 km from the mainland), likely taking advantage of abundant coastal resources to settle regions such as the Americas (Erlandson et al. 2007, 2008, 2015). Interestingly, in some cases these ventures seem largely exploratory with a desire to only acquire resources such as obsidian and not to necessarily establish colonies (e.g., Kozushima, Melos). Incidentally, they also do not coincide with large scale faunal extinctions (Louys et al. 2021).

Not long after, many of the Caribbean islands were settled between 6 and 1 kya, as were those in the Mediterranean, North Atlantic, and Pacific (Anderson 2008; Cherry and Leppard 2015; Fitzpatrick 2013, 2015; see also papers in Boyle and Anderson 2010). The rapid development of sailing and navigational (wayfinding) technologies is astounding, and ultimately led to revolutions in transport and far-reaching effects on how we use the earth’s natural systems.

While this global phenomenon was taking hold, one of the most pivotal seafaring movements was beginning in the crook of seas surrounding the Moluccas between the Philippines and New Guinea. Here, Austronesian-speaking groups that had traveled through the Philippines, perhaps originating in Taiwan, were intruding into occupied territories around 4.5 kya and moved farther eastward, eventually settling the Bismarck Archipelago and Solomon Islands in a region known as Near Oceania (Fig. 4.1). By 3.3–3.0 kya, however, pulses of voyaging activity are seen when islands in western Micronesia like the Marianas (Carson 2008; Hung et al. 2011; Rieth et al. 2019) and Palau (Clark 2005; Fitzpatrick and Jew 2018) were settled temporally alongside the dispersal of Lapita peoples eastward from the Bismarcks to remote archipelagoes such as the Reef Islands, New Caledonia, Vanuatu, Fiji, Tonga, and Samoa (Bedford and Spriggs 2019; Bedford et al. 2006; Kirch 1997a). These forays into Remote Oceania represent the first time in the Pacific where humans sailed to other islands that were not intervisible, indicating the ability to track the rising and falling of stars as a sidereal compass coupled with various techniques such as identifying wave patterns, cloud formations, seabird congregations (signaling land), and known migratory routes of whales. Enhanced knowledge of oceanographic processes—for instance, winds that shifted episodically during El Niño/Southern Oscillation events and favored eastward travel—also likely played a role (Anderson et al. 2006; Finney 2003; Gladwin 1970; Goodwin et al. 2014; Irwin 1994; Lewis 1994; Montenegro et al. 2014, 2016). Archaeological evidence shows that these were not always one-way trips but were repeated to obtain important resources, including obsidian, basalt, and pottery, engage in trade and exchange, find marriage partners, and maintain connections with relatives (e.g., Chiu et al. 2020; Sheppard 1993; Torrence and Swadling 2008; White and Harris 1997).

Key dispersals aside, what had transpired with Lapita and its descendent communities for two millennia also laid the foundation for another major episode in Pacific prehistory—the colonization of East Polynesia beginning 1200–800 years ago (Hunt and Lipo 2008; Kirch 1997b; Sear et al. 2020; Wilmshurst et al. 2011). After a 'long pause' of nearly two millennia, the descendants of Lapita groups in Samoa and/or Tonga spread rapidly across the Eastern Pacific, settling the Cook Islands, the Society Islands, the Marquesas, the Tuamotus, Aotearoa (New Zealand), Rapa Nui (Easter Island), Hawai'i, and many islands in between. It is unclear what exactly spurred these movements, but it seems they probably involved a combination of pushing and pulling factors: exceeding carrying capacity, climate change that caused extended periods of rain or drought affecting agricultural production (Sear et al. 2020), displeasure with local leaders, or simply the desire to explore. There is also a case to be made for religious exile having been the impetus for maritime migration in Polynesia and elsewhere historically (Anderson 2006). These migrations would not have been possible, however, without a combination of new technological developments, primarily double hulled canoes that could carry dozens of people and their provisions along with enhanced knowledge of celestial navigation.

While the motivations that drove Micronesians and Polynesians to search for new islands may never be known entirely, it is clear that they were exceptionally prepared colonizers because they brought with them many of the things needed to survive. These included domesticated animals like pigs, dogs, and chickens; cultigens such as taro, yams, coconut, and breadfruit; resources for manufacturing tools; and ecological knowledge of how to exploit each region's abundant marine resources (e.g., Allen 2002, 2007; Fitzpatrick et al. 2011; Harris and Weisler 2018; Horrocks et al. 2015; Kirch 2017; Lambrides and Weisler 2016; Leach and Davidson 2001; Matisoo-Smith and Robins 2004; Sheppard et al. 2010; Storey et al. 2013; Reepmeyer et al. 2012; Szabó and Amesbury 2011; Weisler and Woodhead 1995). This combination of introduced biota, material culture, and ecological expertise is often described as a "transported landscape" (Anderson 1952) in which Pacific Islanders modified their new island homes based on how and where they lived previously (e.g., see Gosden 1992; Kirch 1983, 2007; Storey et al. 2013). Not only that, but they were able to sail to places like Hawai'i, which was colonized from Central-East Polynesia more than 2200 nautical miles away (as the crow flies). However, this would have been much farther when having to use standard tacking maneuvers in a zig-zag fashion (a.k.a. *beating*) while also harnessing the wind to move in the desired direction. These colonizing events are even more extraordinary knowing that Polynesia comprises 10 million square miles (16 million km^2) of ocean with only around 1000 islands which are extremely remote and mostly low-lying atolls and uplifted limestone.

Considering these oceanographic effects, their remoteness, the technological requirements for sailing, and thousands of years of cultural evolution, it is no surprise then that these islands were settled relatively late. This also means that the islands of Micronesia and Polynesia were devoid of humans for thousands or even millions of years after their emergence, and led to endemic environments that were untouched by humans and extremely sensitive to introduced organisms. For example, as of 2014, 26,608 different terrestrial and marine lineages (vertebrates, invertebrates, plants, amphibians, insects, arthropods, etc.) were recorded in the Hawaiian Islands, including 10,000–10,500 endemics and 5000 non-natives (Evenuis and Miller 2015). This means that Hawai'i, like many other Pacific islands that are distant, ecologically fragile, and settled relatively late by humans, were destined to have their habitats impacted to some degree.

How do we measure these potential impacts (if they occurred), and what can we learn from archaeology to postulate how these findings might affect what humans are doing now and in the future? To do this, we can look to the concept of model systems as a convenient and useful approach.

4.3 Islands as Model Systems

Model systems have been widely used in the fields of molecular biology and ecology. Vitousek (2002:573) notes that these are "a system—which could be a gene and its regulators, an organism, or an ecosystem—that displays a general process or property of interest, in a way that makes it understandable (Vitousek 2002:574)." Given this definition, oceanic islands can serve as useful model systems for understanding human-land interactions (Vitousek 2002:574–575; 2004).

Building on this framework, archaeologists have argued that these types of environments have succumbed to the presence of humans and the purposeful (or accidental) introduction of non-native organisms (DiNapoli and Leppard 2018; Kirch 2007; Fitzpatrick and Erlandson 2018). This follows a human ecodynamics approach which states that humans are an integral part of any environment, that we can look to the past for lessons in sustainability and resilience, and understanding these processes can benefit society at large (Fitzhugh et al. 2019). This is essentially the recognition that *Homo sapiens* cannot be decoupled from their environment and will always be an integral part of their surroundings physically and culturally. Doing so allows us to better explore the effects that our species has had on islands and other landscapes by taking advantage of data deriving from different fields of study that cover the *long durée* of human history—from millennial (archaeology, palaeoecology) to centennial (human cultural history) and decadal or annual scales (e.g., marine biology). These can then all be joined to provide temporal perspectives on environmental influence and change (e.g., see Braje et al. 2017; Erlandson and Rick 2008, 2010; Kirch and Hunt 1997a, b; Fitzpatrick and Keegan 2007; Rick et al. 2013).

Examining how humans have affected islands can be accomplished in different ways archaeologically, but includes identifying the animal and plant species that were present before human arrival (an often difficult task considering the notoriously poor preservation of organic remains in some environments) and determining how humans modified landscapes after colonization. The latter evidence might be things like clearing forests for settlement and agriculture using slash and burn (leading to erosion), the extraction of resources (e.g., timber, stone), diversion of water vis-à-vis canals and irrigation networks, stone construction (e.g., walls, fortifications, fish traps or ponds), and modifying landscapes as populations grow. It is critical that these data also be anchored with good chronologies to ensure that the timing of human occupation is known (e.g., see Wilmshurst et al. 2011; Napolitano et al. 2019).

An excellent example of an oceanic island model system is Hawai'i, which Kirch (2007) notes has:

> (1) relatively late colonization of a previously uninhabited landscape by people with an advanced "Neolithic" form of economy; (2) a short, well-controlled time scale (ca. 1,000 years, C.E. [A.D.] 800-1800 for cultural evolution; (3) near-total isolation of the cultural group after an initial period of colonization and two-way voyaging; (4) a demographic transition from small, low-density populations to large, high density populations; and finally, (5) a major transformation in the scale of sociopolitical complexity, as expressed in social hierarchy, economic control systems, material symbols of rank, monumentality, and similar indices.

While not all Pacific Islands provide the same useful evidence for answering questions regarding human-environmental interactions, Hawai'i, and also New Zealand, provide important case studies for examining these issues. Below I briefly discuss what is observed archaeologically for both archipelagoes in terms of human impacts on birds, which are among the most ecologically sensitive and easily impacted island animals. It is also well documented that humans have had profound effects on these environments, leading to significant impacts on birds globally (Blackburn et al. 2004; Burney 1997; Duncan and Boyer 2002, 2013; Steadman 1995, 2006; Steadman et al. 2002; Weisler and Gargett 1993). These two archipelagos then provide a snapshot of human-induced changes to the islands showing that birds are literally and figuratively 'canaries in a coal mine' and serve as a litmus test for detecting and estimating ecological impacts (see Steadman 2006).

4.4 Islands as Microcosms of Human Destruction

Hawai'i was the most remote group of islands ever colonized by humans in the ancient past. Typical of oceanic archipelagos, the farther they are from mainland areas the more ecologically impoverished they become. This trend is seen in the Pacific where there is a decline in diversity from west to east, known as faunal attenuation (Keast 1996). As noted earlier, these pristine island environments, having been colonized over time by encounters with floating debris carrying seeds, pollen, insects, and animal castaways that do not disperse well over water (e.g., ants, lizards, small mammals), along with flying organisms (primarily birds and occasionally bats), evolved for millions of years with few new migrants. The result was the evolution of biota in near isolation that led to numerous endemics. As Steadman (2006:40) notes, "[t]errestrial biotas in Oceania are influenced by the island's isolation from source areas (usually other islands), size, age, climate, and geological and edaphic environment. Of these attributes, perhaps none is more important than isolation."

Among these biological changes were a tendency for birds to become flightless and ground-dwelling, including rails (Steadman 2006:296–319) and ratites (e.g., the large flightless moa that evolved in New Zealand over millions of years). Flightlessness has evolved in ratites more than in any other group of birds, a trend observed in birds more broadly (Steadman 2006:296). This kind of evolutionary change is not uncommon given the absence of apex predators or terrestrial omnivores that are typically highly mobile and adaptive. For the Pacific Islands, humans were the primary predator and rats were the other, though the introduction of domestic dogs and pigs also played a significant role (Anderson 2009). Dogs, in particular, have served as hunting companions for humans worldwide and are predators themselves (Doherty et al. 2017). In one modern case, a single stray dog roaming the Waitangi State Forest in New Zealand was deemed responsible for killing an estimated 500 North Island Brown Kiwi (*Apteryx australis mantelli*) in a period of weeks or months, which represented more than half the known population of this endangered bird. This kiwi was easy prey since it is known to be a noisy animal with a strong and distinctive smell. Further, given its low reproduction rate, it was estimated that it could take 8–10 years for the population to rebound to its original size of around 900 individuals (Taborsky 1988).

Many mechanisms explain the decline in bird (or other) diversity on islands, but none were as quick or profound as the arrival of humans. It is important to remember that long periods of isolation and evolution led to naïveté toward people—there was no initial fear of predation by these new human colonists or their domestic companions and it would have taken little effort to capture birds or collect their eggs. While the need for food and resources like feathers would have enacted a terrible toll on local avifauna, it was likely the widespread clearance of forests for villages and arable land through burning that accelerated the decimation of island bird diversity.

An excellent case in point was arrival of the Maori to New Zealand around AD 1200 that led to the rapid extinction of nine species of the aforementioned moa, which were overhunted within ~150–200 years (Anderson 1989, 2003). Steadman (2006:405–417) reports that since human arrival in the Pacific, there have been between 820 and 1960 species of passerines (small, perching birds), non-passerine landbirds, and seabirds that have gone extinct, with the number of extirpated populations potentially 10 times higher. In addition, the decline or eradication of certain food resources also caused ecological cascades—the presumed extinction of the Haast's eagle (*Hieraaetus mooreiin*) in New Zealand, the largest eagle ever known (~15 kg) due to its adaptations for hunting moa, went extinct around AD 1400 as its primary food source was removed. Given that these are remote, insular environments, there was little chance for populations to rebound through breeding or immigration like what would have more easily occurred on larger landforms. It should be noted that it is difficult to provide more precise estimates without robust fossil assemblages that pre-date human contact and which are also difficult to find given generally poor preservation and a lack of survey on many islands.

When and how birds and other animals went extinct in the Pacific Islands is variable. However, we must consider issues such as population density and growth, whether occupation was temporary or permanent, if settlements were inland or coastal, subsistence strategies (e.g., hunting-gathering-fishing, horticulture, large scale agriculture), and the types of introduced plants and animals (e.g., degrees of husbandry, roaming and/or feral species) (see Steadman 2006:414). While we may never truly know the amount of Pacific biodiversity prior to human arrival—and thus extirpation or extinction rates—data here and in other island regions such as Madagascar and the Caribbean (e.g., Burney and Flannery 2005; Fitzpatrick and Keegan 2007; Hawkins et al. 2019; Martin and Steadman 1999; Steadman 2006; Steadman et al. 2002) clearly point to varying degrees of ecological destruction, particularly for birds but also many other organisms.

There are numerous explanations for how human impacts on native ecologies played out in the Pacific. These range from perceptions of overly sustainable practices and harmonious relationships (i.e., Polynesian versions of "the noble savage") that had limited to no effects on island biota, to "overkill" or "blitzkrieg" models often used as explanations for megafaunal extinctions during the Pleistocene (e.g., see Barnosky et al. 2004; Brook and Bowman 2004; Grayson and Meltzer 2003; Louys et al. 2007; Rule et al. 2012). In overkill scenarios, species are progressively hunted at a rate where they cannot be replaced (more typical of k-selected species), which may take place over centuries or millennia. By contrast, blitzkrieg models account for humans moving at an extremely rapid pace as they carve a path through the landscape and leave no viable remnants of a given species which would allow it to maintain a sufficient breeding population. In some cases, the reasons behind this are unrelated to subsistence and may involve the desire for other resources like pelts, fur, or feathers; sometimes it is simply done for sport. History is replete with examples of both. These include well-known cases such as (1) the dodo (*Raphus cucullatus*) from the island of Mauritius that was first observed by Dutch sailors in 1598 and last seen only 64 years later after overhunting, habitat destruction, and the introduction of invasives; (2) the American plains bison (*Bison bison bison*) that numbered more than 25–30 million in the sixteenth century, but where overhunting nearly drove it to extinction in the late nineteenth century when only about 100 animals remained; and (3) the passenger pigeon (*Ectopistes migratorius*), which had an estimated population of three billion, but became an important food resource for settlers who migrated westward across the American continent, and subsequently became extinct in the early 1900s due to both overhunting and deforestation.

While these are extreme examples in recent history with no real archaeological corollaries, they do serve as stark reminders of what Garrett Hardin (1968) famously called the "Tragedy of the Commons" in which multiple users of a resource, unrestricted from extracting that resource, will eventually deplete it until nothing is left. With all of the evidence available, can we use the past colonization and settlement of islands as analogues for what we might expect in the future as humans move beyond our 'Earth Island' to other celestial bodies?

4.5 The Colonization of Other Worlds

On December 17, 1903, the Wright brothers took the first controlled flight near Kitty Hawk, North Carolina in an aircraft they built that instigated a technological revolution. It is astonishing that only 24 years later, Charles Lindbergh made his landmark solo non-stop crossing of the Atlantic in the *Spirit of St. Louis* (1927), and eight years after that in 1935, Amelia Earhart flew 2,408 miles from Honolulu to Oakland, CA (Fig. 4.2a). In 1986, Dick Rutan and Jeana Yager completed the first non-stop flight around the world without refueling in the custom-made Rutan Model 76 *Voyager* (Fig. 4.2b).

While advances in aviation quickly altered the fabric of human society, it did not take long for a human-made object to be propelled into space. In 1949, the Germans

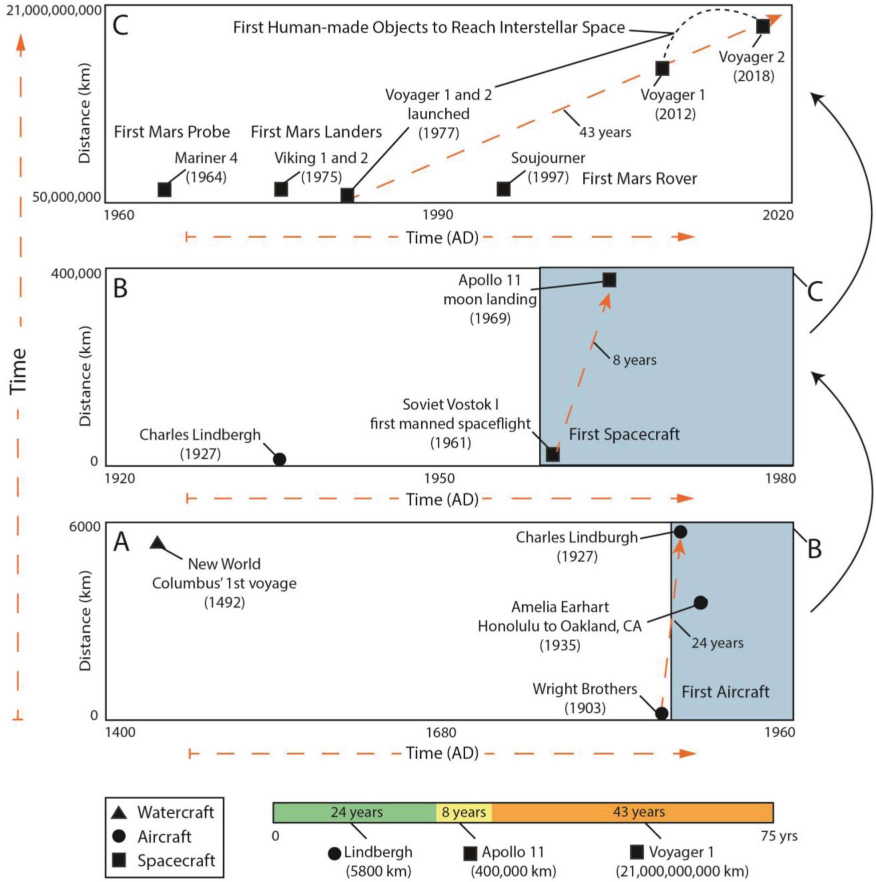

Fig. 4.2 Time slice chart of different transport technologies developed by humans over the last 500 years to colonize or reach different environments and some of the associated significant achievements. Note how distances increase (y axis) over shorter time spans commensurate with the development of more advanced technologies (adapted and revised from Fitzpatrick and Erlandson 2018: Fig. 1). The timeline at the bottom summarizes three of these accomplishments, showing how just 24 years after the Wright Brothers' success, Charles Lindbergh flew 5800 km across the Atlantic; it only took eight years for Apollo 11 to reach the moon after Yuri Gagarin became the first human to orbit Earth in the Soviet *Vostok 1*; and it took only 43 years for *Voyager* 1 to travel 21 billion miles from Earth after it was launched in 1977

launched their "Bumper-WAC" missile atop a V-2 rocket that reached an altitude of 244 miles. Eight years later, and only 54 years after Orville and Wilbur Wright first harnessed the wind in their heavier-than-air contraption, the Soviet Union launched Sputnik 1 on October 4, 1957; a short time later in 1961, Yuri Gagarin became the first human to orbit Earth aboard the Vostok I. Seven years after that in 1968, Apollo 8 became the first manned crew to leave low-Earth orbit and travel around the moon, with astronaut William Anders taking the first 'Earthrise' photo. A short time later, the United States accomplished the extraordinary feat of traveling 385,000 km and landing on the Moon where Neil Armstrong became the first human to step foot on the lunar surface as part of the American Apollo 11 space mission on July 20, 1969 (Fig. 4.2b). Subsequent attempts by NASA eventually led to six more Apollo moon missions between 1969 and 1972 where a total of 12 astronauts eventually walked on its surface, with another (Apollo 13) having to abandon their attempt due to a series of mechanical failures. And how could we forget the *Voyager* 1 and 2 missions, launched in 1977 with the primary goal of exploring Jupiter and Saturn but continuing on to reach interstellar space on August 2012 and November 2018, respectively? They are now between 11 and 14 billion miles from Earth and still sending back important data on the history and composition of our solar system (Fig. 4.2c). What these events demonstrate is that humans have developed increasingly more sophisticated transport technologies over shorter periods of time, allowing us and our machines to go farther and faster in the last 100 years than in the millions before that.

There is no question that these were all extraordinary feats of human ingenuity, perseverance, and engineering prowess. They also continued to whet the appetite of those who would dare to venture beyond the more stable platforms of *terra firma*—not only to the oceans, mountains, and other inhospitable places on Earth—but those moons and planets in our own solar system, namely Mars. The Red Planet has captured the imagination of humans for millennia due to its size and relative proximity to the earth, leading many ancient civilizations to recognize its presence and hue, like the Greeks and Romans who attributed Mars to their gods of war. As a testament to the Red Planet's interest to those of us on Earth, NASA has sent a series of orbiters, landers, and rovers there since 1964, with the Pathfinder mission landing the first rover named *Sojourner* which touched down on July 4, 1997 (Fig. 4.2c). Four other rovers from the United States have successfully landed there and explored the planet's surface, including *Spirit* and *Opportunity* in 2003, *Curiosity* in 2011, and *Perseverance* in 2021 that carried with it the first rotorcraft named Ingenuity. Notably, China landed its first rover on Mars named *Zhurong* in May 2021. Europe's space agency in conjunction with Russia, plans to send another in 2022 named *Rosalind Franklin.*

The fascination with Mars is not only scientific, but pragmatic. As Earth's nearest accessible corollary, researchers are interested in how the planet formed, whether water was present (now confirmed to pre-date life on Earth ca. 3.5 billion years ago; see Deng et al. 2020; Heydari et al. 2020), if there is evidence for past or current lifeforms (still unknown), and a host of other questions. But the Red Planet is also the focus of scholars who believe that it may be the next logical step in a series of major human diasporas as technological innovations improve to the point where interplanetary travel to Mars, and the establishment of colonies, is feasible. Like all such ventures, there are associated costs and underlying reasons that drive the decision by humans to move beyond firm ground and explore environments that may be familiar, but can also be extremely hostile.

The well-known theoretical physicist Stephen Hawking (2010) once stated:

> If we can avoid disaster for the next two centuries, our species should be safe as we spread into space. If we are the only intelligent beings in the galaxy we should make sure we survive and continue…. Our only chance of long-term survival is not to remain inward looking on planet Earth but to spread out into space. We have made remarkable progress in the last hundred years. But if we want to continue beyond the next hundred years, our future is in space.

The "disaster" that Hawking was referring to is not a single, impending cataclysmic event, but a slow train of tragedy involving a myriad of problems that largely began when humans became sedentary agriculturalists between 12 and 3 kya, grew in population, and expanded into nearly every corner of the world. Over the course of the next few millennia, civilizations have risen, technologies improved that have allowed humans to surpass our own physical limitations, and exponential growth, doubling from 3.9 billion to 7.8 billion in less than 50 years. These processes have led to a nearly complete human domination of Earth's terrestrial ecosystems and significant impacts on our hydrosphere and atmosphere.

These events have increased by an order of magnitude to the point where over the last 200 years—largely due to the Industrial Revolution—we have overharvested (and in some cases, exhausted) resources, driven numerous plants and animals to extinction (with many others threatened), extracted materials through subterranean and strip mining to manufacture products we want or need, and caused widespread pollution of land and sea. Testaments to just how far our impacts have reached include microplastics found in the most remote places on Earth, including the tallest mountain, Mt. Everest (Napper et al. 2020) and the world's deepest ocean trenches (Jamieson et al. 2019; Peng et al. 2016). The burning of fossil fuels used in a wide range of industries—and relied upon by much of Earth's population—has led to carbon dioxide emissions that are warming our planet, melting glaciers and polar ice caps, and causing rising sea levels that will continually threaten those who live on islands and low-lying coastal zones, now estimated to be about 10% of our planet's population (760 million people). That some governments, notably the United States, have continued to deemphasize the effects of, or entirely reject, the impending climate change catastrophe—highlighted even more clearly during the Trump administration—is not only irresponsible, but will cause irreparable damage to the places we live and hundreds of millions of other people on our planet who have little to no control over these decisions—they will ultimately be left to the whims of politicians and large corporations who would rather serve their self-interests. Exxon Mobil's well-known history of funding climate change denial organizations and politicians, lobbying against legislation to reduce fossil fuel use, and generally using their political clout to thwart clean energy, is one case in point.

Major disconnects also exist between observable trends in climate change and human dispersal behaviors, evident in the US where population centers in Sunbelt areas like Phoenix are seeing an influx of migrants even as annual average temperatures increase. Historically, humans have occupied habitable niches that average around 55.4 °F (13 °C) (Xu et al. 2020). As the climate crisis continues to grow, many nations will see drastic transformations in temperature and humidity, where certain kinds of food can be grown, and areas of wildfire risk that will stress resources and influence human migration to more northerly and southerly latitudes (see: projects.propublica.org/climate-migration). Even if global population remains static, this will lead to many areas where human habitation is no longer feasible socially or economically. The result will be an amplification of what we are already seeing with climate migration, where millions of people are forced to leave their homes. In 2017 it was estimated that almost 69 million people around the world were displaced forcibly, with about one-third of those due to "sudden onset" weather events, including intensified storms, flooding, and forest fires that occurred after prolonged droughts (The Nansen Imitative 2015). A few years ago, the World Bank (Rigaud et al. 2018) estimated that there will be 143 million more climate migrants by 2050 from just three regions—Southeast Asia, Latin America, and sub-Saharan Africa. Where does that leave us?

If we look at the history of human civilization and the underlying reasons behind why major population dispersals occur, there are some obvious parallels to what is observed archaeologically in the ancient Pacific and what we see happening today. People often leave their homes and seek to establish colonies elsewhere because their societies have exceeded environmental carrying capacity, are overpopulated, oppressed, engaged in conflict, or have overexploited local resources, though it is usually a combination of many (or all) of these factors. But we also cannot discount the inherent curiosity that humans have about what lies beyond. Keegan and Diamond (1984, 1987:67) discussed the concept of 'autocatalysis' which proposes that once people began discovering islands, there was an expectation that there would be more, thereby fueling the drive to continually voyage further. This kind of motivation could have been highly influential in promoting migration in the Pacific and other island regions despite the inherent risks involved. Jennings (1979), for example, proposed that as many as 500,000 Polynesians died in attempts to colonize the region. This is purely speculative as we will never know how many people actually perished on these voyages, a phenomenon I have referred to as the "seafaring paradox" (i.e., in a watery realm where evidence is easily lost, only successful landfalls can be traced archaeologically) (Fitzpatrick 2018). It is reasonable to suggest, however, that there were many failed voyages because of storms, getting lost, illness, exposure, and loss of provisions.

Regardless of what may have motivated Polynesian or other seafarers to colonize islands, the fact remains that we know most voyages were purposeful and not accidental because as noted previously, they brought with them the things they needed to survive for which there is good archaeological evidence. And it is also clear that many of these non-native plants and animals had adverse effects on pristine island ecologies that was only amplified after the arrival of Euro-Americans, new efforts at (re)colonizing, and commercialization ventures. With what we have seen historically in the Pacific, are these reminiscent of what humans will do in the future after leaving Earth? What issues must we consider as we encounter new habitats?

4.6 Transported Landscapes on an Interstellar Scale

As the feasibility for traveling and living beyond Earth becomes more of a reality, what are, or should be, the concerns that we as a species have for impacting other worlds? Are there lessons we have learned here on Earth that we can apply to the process of colonizing planetary bodies in interstellar space? What corollaries can we use to theoretically conceptualize how this might occur?

In a paper that I published with Jon Erlandson (2018) we discussed, albeit briefly, how the prehistoric colonization of islands can serve as useful analogues to the human colonization of environments beyond Earth. This was partly inspired by the work of anthropologist Ben Finney (1985) who, along with the Hawaiian artist and cultural icon Herb Kāne and Tommy Holmes, co-founded the Polynesian Voyaging Society that constructed the famous Hōkūle‘a double-hulled sailing canoe replica and wrote a series of papers on the subject of Pacific voyaging and remote island colonization (see Finney and Jones 1985a, b). Finney's (1985) argument was that these ventures were a testament to how human curiosity, ingenuity, and desire to populate distant landmasses were essentially no different than modern efforts to go into space. Other chapters in the volume by Finney and Jones (1985a, b), written by such illustrious anthropologists and historians as Joseph Birdsell and Alfred Crosby, along with notable scientists like Carl Sagan (1961), also described what the next stages of the human experience might be for humans beyond *terra firma* (see also Broodbank 2018:191).

We took this concept a step further, however, and suggested that the archaeological study of islands under a model systems approach also had implications for understanding and managing the future colonization of planetary bodies (Fitzpatrick and Erlandson 2018; see also Webb 2021). It is becoming increasingly likely that humans at some point in the relatively near future—perhaps this century—will establish a colony on Mars (or at least, that seems a medium or even short-term goal of different private companies and space agencies). As Elon Musk (2020)—the famed CEO of Tesla and SpaceX and strong proponent of Mars colonization remarked recently at a virtual conference on the subject, "[i]f there's something terrible that happens on Earth, either made by humans or natural, we want to have…insurance for life as a whole. Then, there's the kind of excitement and adventure." The development of these hypothetical scenarios are not meaningless exercises. If the predictions by Stephen Hawking and others come true—that humans are causing irreparable harm to Earth's ecosystems—so much so that even current efforts to reduce carbon emissions, curb resource extraction, and implement sustainable practices—then reaching beyond our planet may be the only way for our species to survive. But is this a one-sided, human-centric affair, or should there be other things we consider as we move forward with plans for extra- or multi-planetary settlement?

In a move to highlight the potential pitfalls of planetary colonization, the Equity, Diversity and Inclusion Working Group (EDIWG) for NASA recently presented a white paper titled "Ethical Exploration and the Role of Planetary Protection in Disrupting Colonial Practices" to the Planetary Science and Astrobiology Decadal Survey committee. In this manifesto, published by Tavares et al. (2020:1) and signed by 109 scholars, they state that:

> Ethical considerations must be prioritized in the formation of planetary protection policy. The choices we make in the next decade of space exploration will dictate the future of humanity's presence on other worlds, with the potential to impact the environments we interact with on timescales longer than the human species has existed. We should make these choices consciously and carefully, as many will be irreversible, especially those pertaining to how we interact with potential extraterrestrial life.

They go on to say that:

> … Violent colonial practices and structures—genocide, land appropriation, resource extraction, environmental devastation, and more—have governed exploration on Earth, and if not actively dismantled, will define the methodologies and mindsets we carry forward into space exploration... It is critical that ethics and anticolonial practices are a central consideration of planetary protection. We must actively work to prevent capitalist extraction on other worlds, respect and preserve their environmental systems, and acknowledge the sovereignty and interconnectivity of all life. The urgency of finding a second home on Mars in the shadow of looming environmental catastrophe on Earth is not only a questionable endeavor but scientifically impossible with present technology, and is often used as a justification for human exploration and to suggest that these ethical questions may be antiquated in the face of that reality. Here we argue the opposite: that the future of our own species and our ability to explore space depends on pursuing anticolonial practices on Earth and beyond. An anticolonial perspective can push us towards an ethic that acknowledges our interconnected and entangled lives. Rather than an escape, or a continuation of manifest destiny, the Moon and Mars may provide the key to practicing other ways of exploring and of being (Tavares 2020:1).

Here, Tavares et al. (2020) point to some obvious concerns rooted in the history of speciesism and Western expansionism that still resides in the collective consciousness of those whose relatives (human and non-human) were subjected to enslavement, forced relocation, indiscriminate killing, subjugation, land grabbing, and erosion of cultural lifeways—that we must be considerate of the toll these events have taken on human society and biodiversity, and ways in which we might pause or ameliorate their effects (e.g., see Gamble et al. 2020). While Tavares et al. (2020) argue for a cessation of space exploration and a focus on saving our own planet from our current dilemmas, their fears belie the natural evolution of human behavior—that at some point, we will likely (or must) leave Earth to survive as a species.

Though these philosophical dilemmas will persist, a natural outcome in this scenario—at least in the beginning—will be the transport of things we use on Earth to other places as a matter of necessity. Like Polynesians a millennium ago, there was stark recognition that ultimate survival depended on bringing with them plants to cultivate, animals to raise, and tools that could be used to ensure a successful colony. These were supplemented with centuries of traditional ecological knowledge that allowed these transported landscapes to be implemented and expanded through ‘landscape learning’ of novel environments (Rockman and Steele 2003). The movement of humans to Mars or other moons and planets will involve many of these same processes—but at what cost?

4.7 Lessons for the Future?

In this chapter I have not concerned myself with identifying when various impacts on Earth will become so severe that our survival requires migration beyond our planet, or what can be done to mitigate the effects of human impacts on Earth. The challenges we face—from pollution to climate change, rising sea levels, habitat destruction, overexploitation of resources, and unhindered population growth—are becoming more well documented every year by those who have skill sets beyond my level of expertise. I do, however, want to reiterate what should be some fundamental concerns for future generations involved in the exploration and eventual colonization of planetary bodies beyond our planet.

1. What lessons can we learn from archaeology and the prehistoric settlement of islands to help us better understand the future?

The well-known British naturalist, Sir David Attenborough, recently said in reference to a newly released World Wildlife Fund (WWF) on threats to Earth’s biodiversity that the Anthropocene—a proposed geological epoch created by human dominance of Earth (for archaeologically related discourse, see Braje and Erlandson 2013; Braje et al. 2014; Fitzpatrick and Erlandson 2018; Leppard 2019; Rick et al. 2013)—may be the wake-up call that humans need in effort to reinstate a balance with “the natural world and become stewards of our planet.” But doing so “will require systemic shifts in how we produce food, create energy, manage our oceans and use materials,” Attenborough said, and “above all it will require a change in perspective. A change from viewing nature as something that’s optional or ‘nice to have’ to the single greatest ally we have in restoring balance to our world” (Briggs 2020).

Is this achievable? The same WWF report shows that 20,000 different populations of birds, amphibians, reptiles, fishes, and mammals have declined an average of 68% since 1970 and “a separate intergovernmental panel of scientists concluded that one million species (500,000 animals and plants, and 500,000 insects) are threatened with extinction, some within decades” (Briggs 2020). A report recently released by the National Oceanic and Atmospheric Administration (NOAA) and the University of Maryland that examined the health of coral reefs under U.S. jurisdiction between 2012 and 2018, including those in the Pacific (Guam, Hawai‘i, American Samoa) and Atlantic/Caribbean (Florida, U.S. Virgin Islands, Puerto Rico), show that while many of the more remote islands were “good,” those in South Florida and the Florida Keys were critical. The introduction of sewage, fertilizers, and various other chemicals and pollutants have taken their toll on Gulf Coast coral reefs with only about 2% remaining (NOAA 2020). What these numbers show is that despite some major conservation efforts over the last 50 years across a wide range of habitats on all seven continents—and the bodies of water that separate them—we are reaching a tipping point that will not be easily reconciled, largely due to the rapid and exponential growth of Earth's population that has led to the continued and unsustainable extraction of resources and the overall destruction and pollution of our planet's ecosystems.

What the archaeology of islands has told us is that humans have not often considered the implications of what it means to settle new lands for the first time. There are cases, however, of societies in the Pacific that seem to have recognized patterns of behavior that are detrimental to the health and vitality of the environments in which they live and made corrective decisions to diminish their impact. The island of Tikopia (Bódi and Takács-Sánta 2020; Kirch 1983) is a well-known example, with a strong case being increasingly made for Rapa Nui (Easter Island) (DiNapoli et al. 2021; Mischen and Lipo 2021). There are ones in other island regions like the Mediterranean (Plekhov et al. 2021), Florida Keys (LeFebvre et al. 2022), and Caribbean (Giovas et al. 2013; Poteate et al. 2015) with the latter indicating intensified consumption of marine foods through time but with no apparent impacts on their populations. While there have certainly been some bright moments, history shows that our species will be hard pressed to save ourselves from ourselves. While on vastly different scales, islands and planets, conceptualized as model systems, may be no different in the ways in which they are affected by humans.

2. What can the historical study of islands teach us about colonizing space?

The search for habitable exoplanets is continuing at an ever-increasing pace with scientists around the world using more advanced telescopes, observational satellites, and statistical data-crunching to try and discover planets that may reside in the "Goldilocks Zone" where temperatures and pressures are stable enough (not too high or too cold) for water to remain in its liquid state. It is incredible to think that within our own galaxy, the Milky Way, there could be an estimated 400 billion stars; Earth revolves around just one of those. Bryson et al. (2020), using data from the Kepler space telescope, suggest that within our galaxy there may be close to 300 million Earth-like rocky planets that could potentially be habitable, though our ability to see them up close, let alone visit them, is something not yet attainable and will not be for centuries or millennia to come.

Astronaut William Anders noted after his famous Apollo 8 mission around the moon, "When you're in a spacecraft, you think in terms of oceans of islands" (Earthrise 2018: 0:05:30). On a hypothetical scale, if the history behind human colonization of the Pacific Islands has anything to say, it is that where there is a will, there is a way. Like ancient Pacific Islanders who began to settle Remote Oceania three thousand years ago, they needed to perfect transport (boat construction), determine where they were spatially in the fluid realm of a vast ocean using navigational and wayfinding skills, and carry with them the provisions, tools, and knowledge they needed to increase their chances of establishing a successful and viable colony—the "transported landscape" package mentioned earlier. Irwin (1994, 2008) proposed that to accomplish these feats, different parts of the Pacific had in effect served as "voyaging nurseries" where people could practice their skills, refine their techniques, and slowly but surely expand their search beyond sight of land. There is no question that these were exceptional seafarers, and archaeological evidence attests to their accomplishments, though there were many who surely perished in the attempt or became relatively or completely isolated (Fitzpatrick and Anderson 2008). Planetary migration, using the Moon and Mars as fertile experimental grounds for testing and practicing new forms of transport, may in effect proceed in much the same way.

3. Can islands serve as corollaries for planetary migration?

What we have seen with island colonization in the ancient past that it is a corollary for how humans have approached space exploration. Beginning a little more than a century ago with the Wright Brothers, our skies have served as voyaging nurseries for planes and other mechanical flying machines. These quickly evolved to the propulsion of rockets and satellites through the stratosphere, leading to landings on the moon 50 years ago and now rovers that have explored the surface of Mars that is more than 55 million km away. These extraordinary achievements of human dispersal into unknown and often unpredictable environments are the result of millennia of technological and cultural evolution and hark back to what Keegan and Diamond (1987) termed "autocatalysis"—the notion that if there is one habitable place out there in the distance, there must be more. It is this concept that I believe will continue to spur human exploration of space. But similar to that which likely occurred with Polynesians in the Pacific, there will be both social and economic considerations that factor into the costs and benefits of moving beyond *terra firma.*

While there are a multitude of reasons why our species has sought to explore new worlds, we should be cognizant of the fact that other celestial bodies in our solar system and beyond are macrocosms of islands found on Earth—pristine environments untouched by humans, but that on a geological scale, quickly succumbed to the whims of what Baleé (1998) has called *Homo devestans*—the most destructive and adaptive species on the planet. It must be remembered that the places we eventually colonize beyond Earth are essentially islands floating off in the distance and may have (or had) a long history of biological evolution that could easily be destroyed by our mere presence and that may be equally detrimental to humanity.

4. How will humans approach reaching, living, and interacting with extraterrestrial environments?

In terms of our solar system, researchers are investigating tantalizing clues that there may be life—or the building blocks of life—in a number of places we did not expect. These include the possible presence of phosphine (PH_3, also known as hydrogen phosphide) around Venus (Greaves et al. 2020), which Carl Sagan (1961) had suggested decades ago might be a fruitful place to look for such things. Given that phosphine on Earth is only known to be associated with human and biological sources, closer examination has led scientists to search for explanations as to why this chemical could be found on Venus. One group concluded that "[t]he presence of PH_3…must be the result of a process not previously considered plausible for Venusian conditions. The process could be unknown geochemistry, photochemistry, or even aerial microbial life" (Bains et al. 2020). This is certainly a provocative study, though subsequent analysis of the data suggests phosphine levels are not as high as previously thought. Additionally, a newly discovered ring-shaped molecule called cyclopropenylidene was just found on Titan, one of Saturn's moons (Nixon et al. 2020). While not directly indicative of life, it is a compound that is highly reactive with other molecules, types which tend to be biological building blocks for DNA and importantly, has not been seen before in any other planet or moon's atmosphere. A new spacecraft, *Dragonfly*, is on schedule to be launched in 2027 to take a closer look at Titan's surface and perhaps answer some of these lingering questions about possible extraterrestrial life.

This all leads us back to the Red Planet, which is still the most reasonable candidate for having evidence of life in our solar system given the presence of water that is—at least on Earth—what we think is a required building block. If that is the case, and evidence for life is eventually found, how should that affect our goals and strategies for colonization? Because Mars is inhospitable to humans due to high levels of radiation, a thin atmosphere, and air that is about 95% carbon dioxide, this will require both personal (spacesuits) and large-scale (livable structures) protection from the elements that is relatively low-cost and durable. Interestingly, Shiwei et al. (2020) propose the use of chitinous materials, which is a primary constituent of insect and crustacean exoskeletons and fish scales. They write that the application of: "principles of bioinspired chitinous materials and manufacturing, initially developed for production within circular regional economies on Earth…[could be used to] develop a composite with low manufacturing requirements, ecological integration, and versatile utility in a Martian environment… [and that demonstrate] the development of a closed-loop, zero-waste solutions to tackle unsustainable development on Earth [which] may also be the key to our development as an interplanetary species" (Shiwei et al. 2020:6–7). This is both a novel and feasible pathway for helping to ensure a successful colonizing endeavor and not unlike the intentional transport of materials that Pacific Islanders brought with them such as stone, plants, and animals.

In addition, there are also suggestions of finding ways to potentially terraform Mars and other interplanetary bodies to create habitats for humans that would be less expensive and more conducive to long-term survivability. Elon Musk (2020) has touted the idea that nuclear bombs could be used to vaporize the Red Planet's ice caps to release large amounts of carbon dioxide water vapor that would have the effect of warming the planet's atmosphere which averages a cool -80° Fahrenheit. This and other terraforming ideas, however, pose some philosophical dilemmas—first and foremost, whether it is ethical for us to ever pursue efforts at manipulating a planet's lithosphere, hydrosphere, etc. given that we may not know for sure the impact this could have on known, or unknown, organisms. Do humans have an inalienable right to modify Mars or other planets and moons for the purpose of exploration, colonization, resource extraction, and habitation even if there is no evidence of extraterrestrial life?

In the past, peoples often reached islands with the sole purpose of colonizing them as is seen by the intentional movement of plants and animals. These landscapes were also transformed through burning, earth-moving, agriculture, and construction that allowed humans to survive in what were sometimes very marginal environments such as atolls or extremely remote islands. These activities are visible archaeologically across a broad spectrum of island types and often impacted native flora and fauna (the aforementioned birds being just one example). Though early island colonists were causing upheaval to varying degrees, they were not widespread destructors of these pristine habitats. But if our own more recent history has anything to say about it, it is that religious doctrine and other sociopolitical mechanisms have led our species to believe that we do have certain inalienable rights and dominion not only over all of other species, but even those who may look or act differently. These belief systems have rationalized behaviors which have proven detrimental to the environments we live in, other human societies, and our overall survival.

There is now greater discussion about who will, or whether people/companies /nations should, own the rights to different planets and the resources they may contain. One of Elon Musk's goals is for his company SpaceX to build a Martian colony that eventually supports a million people (see Musk 2017; Salter 2020). In a not-so-hypothetical scenario then, a private company builds the infrastructure, offers transport to Mars, establishes communication networks, provides basic services such as sanitation and food distribution, and charges individuals through different means (e.g., hard currency, indentured servitude) for the ability to live and work there. Though on the surface this seems nefarious, it is not unlike the scenario that many immigrants to the United States faced in the 19th and early twentieth centuries. It also would not violate agreed upon stipulations outlined in the 1967 Outer Space Treaty, often referred to as the "Magna Carta of Space."

For the most part, neither Mars nor other celestial bodies provide any real economic incentive to establish a colony. The mineral resources found on the Red Planet are substantial, but currently not economically viable for mining and shipment back to Earth, which would require transporting huge amounts of equipment and personnel. The most likely rationale for human colonization of the Red Planet would be to determine ways in which our species could survive the physically and psychologically grueling trip through space for 5–9 months using current technologies—a testing ground if you will—for eventual settlement and residence that lasts years or even decades. Similar to what probably occurred in the Pacific during Polynesian expansion, it is equally plausible that some Mars colonists would face the precarious reality of never coming home even if they initially arrived safely.

However, given that space tourism is becoming more of a reality, with companies like Virgin Galactic trying to meld suborbital visits with scientific research, it may be that the super wealthy like Richard Branson and Jeff Bezos, eager to go where no human has gone before, will help to bankroll the first visits to Mars. There is also much discussion on how to build bigger and better rockets that could carry enormous payloads—hundreds of metric tons versus what is currently possible (the Saturn V moon rocket built by NASA holds the record at 135 metric tons) and could cut the trip to three months using thermal nuclear engines now in development.[3] This also raises the question of who could eventually lay claim to different parts of Mars—would this be similar to America's "manifest destiny" that justified expansion across the country regardless of who or what was there?

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[3] It is possible that thermal nuclear engines that are twice as efficient as standard chemical propulsion engines could reduce the length of a trip to Mars to three months (Delbert 2020).

5. Are there lessons we have learned here on Earth that we can apply to the process of colonizing planetary bodies in interstellar space?

The archaeological record for Hawaii, New Zealand, and many other islands clearly demonstrates how humans have not only impacted these pristine environments, but how new human groups who came afterward—for the specific purpose of colonizing—unintentionally (at least initially) annihilated Indigenous peoples through the transfer of communicable diseases like measles, smallpox, and other pathogens (Gamble et al. 2020). But, these occurred on our own planet which has an evolutionary history that connects the earth's biodiversity. One can imagine how different and even more dramatic the effects of biological contact would be on a planet with no previous connection to Earth's biosystems. This was something that NASA scientists were concerned about from the beginning and developed procedures to sterilize spacecraft to avoid potentially contaminating the moon or other planets and vice versa (see Webb 2021).

While not mutually exclusive, we should also be cognizant of how humans might affect physical (abiotic) environments. Though my primary concern in this chapter has been to highlight the ways in which humans have impacted Earth's biosystems and projecting what might occur to extraterrestrial (biotic) life, we should be equally concerned as to how we might affect the various landforms on moons or planets that give insight into their formation over time. Though still in its infancy, our efforts at interplanetary exploration has already revealed important information on the geological, climatological, and other processes that have shaped these worlds. One might imagine a known or perceived lack of biota providing an excuse for extracting resources through mining or other destructive activities that wreaks havoc on the landscapes of celestial bodies. Afterall, what has prevented this from happening on Earth even when the presence of biological diversity is known?

There are many other lessons to be learned from the impact of humans first reaching remote islands that had evolved for millions of years without our interference, European arrival on Indigenous populations in the Americas, and the exploitation or eradication of species both accidentally and purposefully (Jackson et al. 2001). The wholesale transfer of biota (plants, animals, insects, microbiomes, and pathogens) between the Old World and the Americas as part of the Columbian Exchange (Crosby 2003) began almost immediately after the arrival of Europeans to the Caribbean islands in AD 1492. This was one of the most pivotal points in human history, leading to biotic transfers that permanently transformed landscapes and human societies, including the introduction of many diseases for which Indigenous peoples had no natural immunity.

What these events demonstrate is that archaeology and history are crucial facets for understanding the ways in which humans have settled and transformed island environments. The end results have not always been ideal—in fact, examples abound for how new colonizing groups caused irreparable damage and transformed landscapes. For traditional societies, this seems to have been the exception rather than the rule for much of the Pacific, at least until Europeans arrived and commercial ventures began taking place (whaling, fishing, mining, etc.) that have largely devastated many island ecologies.

So, should there be things we consider as our species moves toward plans for extra- or multi-planetary settlement (e.g., biotic exchange) based on what archaeology has found? Musk (2020:46) notes that to find a path forward, "[t]he values that we take with us into space exploration should be front and center." As an archaeologist who works on islands, I could not agree more, for islands serve as a stark reminder of what can happen to those who are interested in this pursuit. But what are these values? Are they those that prioritize humans over other lifeforms, as we have on Earth for much of our existence? Or will they reflect the lessons we've learned from the havoc we have wrought on our own planet and simply imprint these onto other worlds? There is no clear-cut answer, but I would argue that we must continue to look to the past, lest we fail to understand the implications of our actions and Earth simply becomes the detritus of a coming world.

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Chapter 5
Species, God, and Dominion

John S. Wilkins

Abstract Species as a concept is the outcome of theological and philosophical considerations, not empirical or scientific need. It still holds political import for the religious movement of dominionism, with great impact on environmentalist and conservationist politics in the United States and elsewhere in the world. This chapter will argue that having a "theoretical" notion of species is inimical to science and polity. It is not needed, as it retains much of its original essentialistic religious origins and emphasizes human exceptionalism to the detriment of ecological stewardship.

5.1 Introduction

Why do we in the West think that human beings are special? Since every species is special (or else it would not *be* a species—*special* is the adjective of *species*), what is so special about *Homo sapiens* that the needs of humans supplant the needs of all other species, unless the needs of humans are met by other species? I will argue that human exceptionalism results from modern interpretations of the biblical narratives, economic motives, and sociocultural accidents.[1]

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[1] It has been suggested that humans are basically selfish: as *Frankie and Johnny* has it, "This story has no moral, this story has no end. This story just goes to show, that there ain't no good in men." However, I think that human exceptionalism is somewhat different to basic selfishness. It is the view that somehow the entire world is for the benefit of humans, a view held by Stoics and Christians, at least in the West.

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Technical terms in science are sometimes treated as contrary to religious doctrines, yet scientific terms shade from foreign intruders in religious usage to comfortable ideas that no believers need to worry about. For instance, the Bible does not recognize *mammals* (since they were first defined by Linnaeus in 1735), but religious folk seem to have no issue with using that notion in ordinary life; while other terms, like *fish*, which includes both crocodiles and cetaceans in the Bible: Gen 1:26, 28; Job 41:1 (Worster 1994; Burnett 2007), have in the past caused dissonance between sociocultural and religious usages and scientific discourse. *Species* is a technical scientific term with scientific, religious, and political overtones, which I wish to review here. Ironically, the term and concept of biological species itself (as opposed to the numerous other uses of the term in theology, chemistry, and other discourses) derives not only from a Christian context, but from Christian biblical exegesis in the context of early modern science.

Moreover, modern environmentalism is focused firmly upon preserving species and not, say, genes or trophic cascades. This means that *species* is a crucial term in debates regarding either conserving nature or utilizing it. Individual species then become the flag on the mast for different locales and situations. The United States '*Endangered Species Act* of 1973 made identifying species critical in the politics of the environment.[2] Therefore, Christian reactions to environmental issues and movements have tended to focus upon species and the specificity of humans in contrast to other organisms. This means that the "archaeology," as Foucault would call it (1970), of this concept in natural science has implications for bad decisions, confusions, and bad policy. The past is retained in some fashion, thus influencing the present.

5.2 Species: Why Do They Matter to Religion?

The "default" Christian view of nature, according to many introductory books and papers, is that humanity (or in patriarchal language, "Man") is separate from and superior to nature, and so it may be exploited for human benefit. There is some truth to this, and it persists among some religious thinkers (Rossello 2017), but as usual in the history of ideas, the reality is more complicated than that. Lynn White Jr. was a historian of technology at Princeton, who argued that Christian views of nature caused the growing environmental catastrophe (at the time, in the early 1960s, mostly industrial and agricultural pollution). He argued that the roots of our ecological crisis lay in the middle ages (White 1967). Before Christianity became the foundation of modern social, political, and economic activity and institutions in the west, pagans believed natural things had spirits (e.g., *genii locorum*). Christianity, he said, established (in the west) a separation of Man from nature, over which Man had dominion (*Genesis* 1:21, 24–26). His ideas were immensely influential in conservation thought, with one environmental historian, Gilbert LaFreniere, calling him (and Roderick Nash) "brave souls in academia" who "dared to make some powerful

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[2] United States (1973); see Green (2005), Taylor et al. (2005).

generalizations regarding medieval evaluations of nature" (Nash 1976, 1989; LaFreniere 2007). Although the White Hypothesis was severely criticized by historians (Whitney 2013; LeVasseur and Peterson 2016), the critique he offered (as a Christian) stung many Christians deeply. There were two general responses—one was to devise a theology that was pro-environmentalist. The other was to set up a reactionary theology. These are referred to, respectively, as *stewardship* and *dominionism.* Early signs of dominionism in public life came in the 1980s with the rise of the political influence of evangelicals in the Reagan administration. White himself noted the tendency of Christian thought to hold that

> ... it is God's will that man exploit nature for his own ends.

This is illustrated well in the 1852 text on *A complete guide to the mystery and management of bees*, by James Beesley (as clear a case of nominative determinism as I have seen), who wrote in his Chap. 3.

> … it is well worth our attention to contemplate the works of our good and great Creator; how and in what a wonderful manner He provides food for all His creatures, from the lowest insect to the lord of the forest, all of which He hath created for His own wise purposes, and for the benefit of man! How beautifully every field and meadow is adorned and variegated; not so much to please the eye, as to provide food for His creatures, the least and most despicable of which are not beneath the watchful eye of Providence, who has wisely ordained, that every plant, flower, shrub, and tree, should produce something for the support of some species of the animal creation!

White quoted "the [then] governor of California" (Ronald Reagan): "when you've seen one redwood tree, you've seen them all."[3] White claimed that the standard theology of Western Christianity thought of living objects as just things, to which humans had no moral obligations, and instead recommended eastern Christian views, including the Eastern Orthodox theological positions, in which nature was valued as a message from God: "In the early Church, and always in the Greek East, nature was conceived primarily as a symbolic system through which God speaks to men."

A "Christian ecology" movement, the Stewards, did arise after this, but it seems to have involved just the elite—theologians, clergy, and activists—with little effect on ordinary lay Christians.[4] And in reaction to what attempts were made to be more ecological in theology, both Christian politicians and conservative thinkers still asserted the "Reagan" view (cf. the "Cornwall Alliance" below).

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[3] This is paraphrased. According to Snopes, 7 June 2006 (https://www.snopes.com/fact-check/if-youve-seen-one-tree/)—what he actually said was "I mean, if you've looked at a hundred thousand acres or so of trees—you know, a tree is a tree, how many more do you need to look at?" Later James Watt, his Secretary of the Interior and a Christian fundamentalist, implied at his confirmation hearings that Jesus would return before ecological collapse, although later he walked that back (*Washington Post*, "The Watt Controversy" June 30, 1981).

[4] Harrison and Berry (2006).

5.3 The Problem of Kinds on the Ark

Ironically, and unsurprisingly to any reader of western history, theology had already played a role in these scientific issues in the very early scientific revolution. Even the notion of *species* in biology (or in natural history as it was then) was the outcome of theological events and arguments (Wilkins 2018). The irony of this is equalled by how Christian thinkers and activists currently treat species. During the fifteenth century, beginning with the Castillian theologian Alonso (or Alfonso) Madrigal, el Tostado, in his commentary on *Genesis* around 1436,[5] followed by Johannes Buteo's (*De arca Noe*) in 1554 (Buteo 1554, 2008), theologians began to take the literal meanings of *Genesis* seriously and try to work through the logistics of Noah's Ark, as the burgeoning humanist movement required when interpreting historical texts.[6] This logistical interpretive movement of Genesis culminated in the work of the Jesuit polymath, Athanasius Kircher, who also published a text entitled *De Arca Noë* in 1675 (Kircher 1675). Kircher, known as "the last man who knew everything" (Findlen 2004), needed to fit all the "kinds" (Latin: *species*) on the Ark and supposed there were around 310 quadrupeds and several score bird species on the Ark. He did not use *species* as a biological term, but, as western philosophy had since the classical era, as a **logical** term, roughly equivalent to our notion of "subset," with *genus* as the equivalent to "set." Hence, a species could be a genus for kinds within it. However, the later logical tradition would also use the term "subaltern genus." The final species in the logic of division, the least division one could make before individuals were identified, was the *infimae species* or "smallest kind." Since this era was marked by exploration and reports of numerous new kinds of plants and animals, it was quite clear that the Ark could not accommodate all of them, and so a mechanism for the generation of new species had to be offered (in the seventeenth century, no less). He proposed that thousands of species of animals formed by hybridization or spontaneous generation, which was a standard western view since classical times. In the Christian tradition, spontaneous generation was reserved for those animals that did not have breath—basically invertebrates such as worms and insects that formed from worm-like grubs.

5.4 The Invention of [Biological] Species

Naturalists continued to use the term "species" in a vernacular way from the 1500s (e.g., Gesner, Jung, Bauhin, Aldrovani), but they were also as likely to use *genus, stirpes,* or several other Latin terms and phrases to denote the kinds of living things.[7]

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[5] Hansen and Franck (1901), 109n. It is remarkably hard to find the original date of this commentary, but the *Opera* was published in 1619.

[6] See Wilkins (2018), 56–62.

[7] For example, Leonhart Fuchs in his "great herbal" (Fuchs 1542; Classen 2001) does not use *species*, but *genera*, and he refers to "plants" (i.e., kinds) as *stirpes*. Earlier, Otto Brunfels' *Herbarum vivae*

Shortly before Kircher's *Arca Noë*, Bishop John Wilkins[8] wrote his *Essay toward a real character and a philosophical language*.[9] He attempted to categorize all things in an artificial language designed to formalize both ontology and debate. He included lists of species drawn up by the botanist Rev. John Ray.[10] Wilkins' schema forced all species (living and non-living) into predetermined linguistic categories which forced Ray to place all species under artificial genera. Ray got a lot of criticism from leading naturalists such as Morison, so he wrote that he needed a definition of the kinds/species to justify his work cataloguing plants:

> So that the number of plants can be gone into and the division of these same plants set out, we must look for some signs or indications of their specific distinction (as they call it). But although I have searched long and hard nothing more definite occurs than **distinct propagation from seed** [*distincta propagatio ex semine*]. Therefore whatever differences arise from a seed of a particular kind of plant either in an individual or in a species, they are accidental and not specific. For they do not propagate their species again from seed; …. But those which never arise with the same appearance from seed, are indeed to be considered specific; or if comparison is made between two kinds of plant, those plants which do not arise from the seed of one or the other, nor when sown from seed are ever changed one into the other, these finally are distinct in species. (Ray 1686, Chap. 20, translation by Lazenby 1995; emphasis added)

and he applied this also to animals, which is not surprising given that he worked on his benefactor and collaborator, Frances Willughby's zoological catalogue after the latter's death in 1672:

> For thus in animals a distinction of sexes does not suffice for proving a diversity of species, because both sexes arise from the same kind of seed and frequently from the same parents, although by many striking accidents they differ among themselves. … So, equally in plants, there is no more certain indication of a sameness of species than to be born from the seed of the same plant either specifically or individually. For those which differ in species keep their own species for ever, and one does not arise from the seed of the other and vice versa. (*Loc. cit.*)

Ray's was the first **biological** definition of *species*. He used it as a diagnostic criterion, assuming an underlying biological ("physiological") generative power. This immediately caused problems, as the number of species Ray and others identified stretched the limits of what could fit upon the Ark, so a solution was reached whereby the species on the Ark were much broader than our modern concept—making use of Aristotle's idea that new kinds of animals form by hybridization.[11] In short, according to this truism adopted after that, more species were formed by

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eicones (Brunfels 1530) has no basic term for plant kinds, but as he uses forms of flowers and the like to group them, it is implied that they exist.

[8] No close relation to the author, alas.

[9] Wilkins (1970, 2002).

[10] Cain (1999), Wilkins (2019).

[11] My 2018 gives the history of this tradition and references for what follows. The idea that novel species are formed from hybridisation is repeated in Pliny, Walter Raleigh, and so on up to Buffon. It is recently accepted as a major mode of speciation (Barrington et al. 1989, Enenkel 2014, Alix et al. 2017).

hybrid events between "created" kinds (of what we would now consider not closely related species). Other organisms, those that did not breathe, such as worms and insects, according to the natural history of the time, were formed out of mud spontaneously (*generatio equivoca*) (Gasking 1967). Moreover, each species was thought to be affected by its locale and environment to take on divergent forms, a view that persisted until the nineteenth century. This idea meant that many naturalists were extreme lumpers, treating similar taxa as the "same" species. Later taxonomists of a more exact kind, such as Adanson and Jussieu, also focused on distinguishing features, or "characters," but used multiple characters rather than a few. Ray's definition was adopted by Linnaeus, Lamarck, and later by Cuvier.[12] Lamarck, for instance, wrote

> Any collection of like individuals which were produced by others similar to themselves is called a species.

Geoffroy Saint-Hilaire:

> The species is a collection or a succession of individuals characterized by a whole of distinctive features whose transmission is natural, regular and indefinite in the current order of things.

Cuvier, whose definition dominated the nineteenth century, defined a species as:

> those individuals that originate from one another or from common parents and those which resemble them as much as one another.

The key concepts are *resemblance* and *generation* or *genealogy*.[13] I have called this the *generative conception* of species, and in *Species: The Evolution of the Idea* (2018), I have argued that this is the definition at the base of all species "concepts" over the history of at least botany, from the early modern era until the modern day.

5.5 Setting the Baseline

The concept of species is, in logic and biology, a baseline group and an elemental kind. Species in biology have been called the "units" of evolution, of biodiversity, and even of selection (Hull 1977; Ereshefsky 1992; Claridge et al. 1997; Green 2005; Hohenegger 2014). They are the smallest obligatory ranks in the Linnean hierarchy of taxonomy and are the smallest name bearers in biological nomenclature. Many biologists think of species as a privileged level of organization, although recent work has challenged this (Ereshefsky 1998; Mishler 1999, 2010; Mishler and Wilkins 2018).

Creationists, however, found them to be **too** small, and from the 1920s on, the "kinds" were increased in scale, leading to hyperevolutionary scenarios (not unlike

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[12] See Wilkins 2009 for references.

[13] Citations and quotations from Wilkins 2009.

Kircher's). God creates basic kinds in a single act, which with terrible Hebraism they call *baramins* (Marsh 1941; Numbers 2006). Under this approach, only a few baramins were on the Ark, but there was "microevolution" (evolution within the limits of these created kinds). Since there are tens of millions of species in modern biological systematics, this is a massive amount of evolution required by creationists in only a few thousand years. Interestingly, though, Kircher's view was also held by many naturalists who were either devout or not (Buffon being one such; to call him heterodox is an understatement).

While Ray and Linnaeus were creationists, this was due to their piety, which did not interfere with good science. There had been a longstanding theological doctrine, due to Augustine (Augustine 1982), that God created the earth with *potentia* to develop new kinds (reading *Genesis* 1:12 "And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good"—as a statement of the power of the ground to generate new plants that could subsequently breed true). The notion that all created kinds were realized on the days of creation was not the only orthodox view in western Christianity.

On the other hand, modern biblical literalists need to shoehorn increasing biodiversity into a small box (literally!) They often, indeed usually, tie this into a view of ecology.

5.6 The Evangelical Backlash Against Ecology

5.6.1 Dominionism and Dominion Theology

> When I consider thy heavens, the work of thy fingers, the moon and the stars, which thou hast ordained; what is man, that thou art mindful of him? and the son of man, that thou visitest him? For thou hast made him a little lower than the angels,[14] and hast crowned him with glory and honour. Thou madest him to have dominion over the works of thy hands; thou hast put all things under his feet: all sheep and oxen, yea, and the beasts of the field; the fowl of the air, and the fish of the sea, and whatsoever passeth through the paths of the seas. [Psalm 8:3–8, *Authorised (King James) Version* of 1611]

Christian human exceptionalism has a long history, but the foundational text for the notion that humans (and particularly those chosen by God) have control over the living world is Psalm 8. Here there is a strong hierarchy in the scheme of the world, and while God dominates (rules) humanity, humanity dominates the rest of the living

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[14] The word for *angels* in Hebrew used here is *mê·'ĕ·lō·hîm* מֵאֱלֹהִים. Early in the history of the religion of the Israelites, they were henotheists (adherents of a tribal, or national, god, one among many others), but by the time the Tanakh was translated into Greek—the Septuagint—exclusive monotheism had taken hold and *elohim* had become "God" rather than "the gods" (Smith 2001, 2002), or else it was used for angels and prophets. The Christian tradition followed this early rabbinic interpretation, as it did with Psalm 82:1 (with Jesus' authority; see John 10:34ff where Jesus states that "the gods" are those to whom God's message has been given).

world. This is one of those passages in the Bible where a natural taxonomy is used to justify some state of things as "right" or "according to God's plan."[15]

There is a form of Christian evangelical theology that has come to be known as *Dominionism* (McVicar 2013). This view is an outgrowth of a theological tradition in the U.S., known as Christian Reconstructionism. Associated with the ideas of R. J. Rushdoony (1916–2001), it broadly holds the view that it is mandated by Genesis 1:26–28 that Christians (and only Christians) should rule the earth and its peoples. An eschatological movement outgrowth of Presbyterianism, it is a "post-millennial" movement in which the Rapture and Christ's return will occur after a thousand years of a Golden Age of Christian dominance. Rushdoony called this *theonomy* since society's rules will be Christian due to the educational, legal, and political control of secular institutions. Dominionism is broadly opposed to ecological concerns. Maltby notes

> Evidently, Dominionist philosophy does not recognize natural entities and species as autonomous life forms; rather, it perceives them as artifacts designed to satisfy human needs. Indeed, according to fundamentalist economist E. Calvin Beisner, to put the Earth before human needs is to be guilty of "idolatry of nature" (Maltby 2008, p. 120)

Maltby goes on to say

> not only is conservation seen as irrelevant, insofar as the planet is thought to have no future (in the words of the 19th-century premillennialist Dwight Moody, "You don't polish the brass of a sinking ship" …), but environmental catastrophe is positively welcomed by Pat Robertson and other fundamentalist leaders as presaging the Rapture and the Second Coming.

As Maltby documents, these movements have deep-pocket conservative funders. The Acton Institute, which is home to this anti-environment movement, is funded by, among others, Exxon-Mobil. Many resource-based companies invested in a fake grassroots ("astroturf"[16]) movement known as the "Wise Use" movement: Amoco, British Petroleum, Chevron, Exxon-Mobil, Marathon Oil, as well as the American Farm Bureau, Dupont, Yamaha, General Electric, General Motors, National Cattlemen's Association, and the National Rifle Association. The phrase "wise use," like "sustainable development," is a subtle cue (a "dog whistle") to the political ecology underlying the ideas of a writer or institution.

The evident capitalist nature of the dominionist and wise use movements, along with other movements like "property rights" (a misnomer since it means using public lands for private purposes) in the United States, appears to be driven mainly by corporate interests (Luke 1998). However, there is also an ideological base known as "Traditionalism." A cross-religion eclectic philosophy, Traditionalism has influenced oligarchs in Russia, industrialists in the U.S., and many other elite groups (Sedgwick 2004). The core tenets of Traditionalism are hyper-conservative: as society moves

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[15] Although interestingly and to the point, the taxonomy here is focused on domesticated animals, rather than wild ones, which makes the dominion primarily over cattle and so forth, and only secondarily over wild creatures. See Whitekettle (2006).

[16] This utilised the playbook of the public relations programs of tobacco companies, often with the same PR firms and players. See Oreskes and Conway (2010).

away from traditional metaphysics, ethics, and politics, it degrades. The originators of Traditionalism, René Guénot, Julius Evola (a racist, fascist occultist[17]), Frithjof Schuon (Hindu influenced), and Mircea Eliade (a scholar of religion), were Muslim or Catholic or influenced by Hinduism. Still, the philosophy itself is more Platonic and involves both a view of a lost "Golden Age" and an eternal return of history. It claims to understand both a perennial religion and a perennial wisdom, both of which are thought to be included in every religion. In principle, Traditionalism, or Perennial or Esoteric Wisdom, opposes modernist societies and modernism. It is an open question whether corporatist thinkers have adopted Traditionalism because it suits the interests of the corporations the believers own or whether the ideology influences them to become corporatists. I tend to think the former is more correct. However, while Traditionalist corporations may fund it, Dominionism is nevertheless an evangelical Christian creation that stands on its own.

The pre-eminent "think-tank" of dominion-style ecotheology is the Cornwall Alliance. Their statement of intent has changed in emphasis over the years, but not its conceptual content:

> WHAT WE BELIEVE
>
> We believe Earth and its ecosystems—created by God's intelligent design and infinite power and sustained by His faithful providence—are robust, resilient, self-regulating, and self-correcting, admirably suited for human flourishing, and displaying His glory. Earth's climate system is no exception. Recent global warming is one of many natural cycles of warming and cooling in geologic history.[18]

The politicization of science by conservatives in America and elsewhere (Mooney 2005) has led to a devaluation of biological diversity in favor of social and economic goals, and to attempts in conservationism and ecology to cast the non-human world as having "ecological services" to influence conservative economic movements (Williams et al. 1996; Faith 1997). This has been adopted quite enthusiastically by the protestant evangelical Pentecostal movement. Evangelicals who oppose ecological conservation treat it as a secular "worldview" that opposes the gospel. Their motivation, however, is not theological: it is the Prosperity Gospel. Berger (2008) notes:

> Weber believed (correctly, I think) that the socio-economic consequences of Protestantism were unintended. Luther, Calvin, and Wesley did not intend their moral teachings to make their followers rich (though at least the last of the three noticed, with considerable discomfort, that many of his followers did become rich—the "method" of Methodism turned out to have an economic result along with its religious one). The purveyors of the prosperity gospel are, as it were, intentional Weberians: They consciously intend the consequences that earlier Protestants brought about unintentionally. Sociologists will have a hard time quarreling with this program, whatever the qualms of theologians.

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[17] Ferraresi (1987).

[18] *Cornwall Alliance* accessed May 2013. This has now been replaced by a much longer and less overt set of documents expressing total dominion over the environment—https://cornwallalliance.org/landmark-documents/, accessed 25 July 2020.

The idea that God favors those who are wealthy, or rather that those who are wealthy are favored by God, is an old view (as Weber argued), but this "intentional Weberianism" was made famous in the United States by Andrew Carnegie's "Wealth" (Carnegie 1889, later retitled "The Gospel of Wealth" in 1901) but in its religious form Prosperity Theology was settled in the 1950s onwards, and became the guiding view of the Pentecostal, and later more broadly the Charismatic, movements of the 1980s. Many Dominionists, such as Joel Osteen, Kenneth Copeland, and Pat Robertson, either promote the theology or are connected to it in various ways. It has become the heresy *du jour* of the popular church. Therefore, using nature to gain wealth is a trendy idea that ties closely to the belief in the uniqueness of human beings as separate from nature. As Cornwall in 2013 states:

> Environmentalism sees human beings principally as consumers and polluters who are only quantitatively, not qualitatively, different from other species. The Bible sees people as made in God's image, qualitatively different from all other species, and designed to be producers and stewards who, within a just and free social order, can create more resources than they consume and ensure a clean, healthful, and beautiful environment.

Dominionism, when post-millenarian, also harkens to a Golden Age, only it is not one we return to but one we will encounter once Christianity rules the world and the route to that age is to encourage the second coming through the exploitation of the earth, among other things (such as war in the middle east, etc.). Religious opponents of environmentalism tend to move "upwards" from species to determine what counts as important, partly due to Noah's Ark and partly to the Christian right's underlying gospel of wealth theology. Humans are exceptional—a little lower than the angels.[19] Dominionists like Joel Osteen desire to have humans separated from nature so that that money can be made. Dominionism may be more influential than Christian stewardship in popular Christian thinking, as is often the case with "elite" ideas in theology versus "folk" ideas.[20]

5.7 We Don't Need Species Anyway

In my view, *species* in biology result from religious and philosophical beliefs and is not a necessary theoretical concept of science.[21] Given the ubiquity of the use of the

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[19] Although, according to *Ecclesiastes* 3:19–20, "For that which befalleth the sons of men befalleth beasts; even one thing befalleth them: as the one dieth, so dieth the other; yea, they have all one breath; so that a man hath no preeminence above a beast: for all is vanity. All go unto one place; all are of the dust, and all turn to dust again." The notion of human exceptionalism is not baked into Abrahamic religions, even if it is the western Christian default. However, *Ecclesiastes* is dated to the latter half of the third century BCE which is quite late, and so the older view of Psalm 8 is more influential on western Christianity.

[20] On this distinction, and its basis in Pike's *etic/emic* distinction (Pike 1954, Jardine 2004), see Chap. 1 of Kapalo 2011.

[21] Mishler and Wilkins (2018), Wilkins (2018) Chap. 14.

term species and the arguments about whether something (like the red wolf[22]) is a species, this might seem a surprising statement. However, when we look at the **use** of the term, it is clear that what biologists are doing is using the *sign* “species” to denote various and distinct notions (*significations* in semiotics) within each discipline, such as “trophic node” or “population” or “form,” and so forth.[23] But the notion that biological diversity is measured by the number of endemic and introduced species in an ecological region is confounded by this disciplinary relativity. For this reason, others have focused upon phylogenetic diversity (Faith 1992) or genetic diversity (Groves et al. 2017) as a “true” metric of the diversity that requires conservation efforts. In short, Ecology uses “species” as a surrogate for trophic roles or nodes, genetics uses “species” as a surrogate for genomes or genotypes, and developmental biology uses “species” as a surrogate for a typical life cycle. Systematics uses species as a surrogate for one or more specimens (or rather, uses specimens as a surrogate for species names). It seems that given the fact there are no universally accepted definitions of species, a pluralistic approach would undercut the need for *species* at all. However, I have argued that specialists will always describe species according to the practices and common properties within the groups of organisms in each specialty. They are more or less conventions in each field that act as phenomena in need of explanation.[24] We are wedded to species, at least for now, because we start with historical and folk taxonomy. Suppose species are just “kinds,” like other taxonomic ranks. In that case, we can find kinds of living things at any scale (and at the evolutionary level, we can simply describe the smallest clades that our analyses discriminate, which Mishler and I have called SNaRCs—the smallest named and registered clades). We need to achieve what is essential—conservation, understanding, inferences—from the diversity of life to whether species are necessary units.

What do we need species for in theory? We can do without them if we need to. They are the result of *emic* definitions within localized subspecialties. They have, however, no *etic* unitary meaning, to hijack Pike’s distinction. This implies that there is no privileged unit in biology, and hence no universal ranks. So, if species are not theoretical objects (ranks or grades), what kind of objects are they? Kant divided terms (in science as in other domains) into those that are about what exists—Ontology/Noumena (“Objects” or “Things”)—and those that are about what we observe—Epistemology/Phenomena (“Appearances”). In keeping with the history and etymology of the **term** *species*, we can say species are phenomena—they are appearances, and appearances do not necessarily give us the things (Massimi 2008; Leonelli 2009). For scientific theories, the things are whatever it is that explains species phenomena. Species are what must be explained (*explananda*), not the things that do the explaining (*explanantia*). We are no worse off without theoretical species;

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[22] See Brownlow (1996).

[23] See my discussion of basic notions underlying the use of *species* in chapter 14 of my 2018.

[24] I argue this more in chapter 5 in *Species Problems & Beyond*, CRC Press 2022, entitled “The Good Species.” In brief, I treat terms like “species” to be “operative concepts,” which evolve due to relatively atheoretical and often conventional practices in each subdiscipline, and which are then subjected to a search for theoretical meanings.

the explanations are still there for the phenomena if we abandon the notion of a universal kind. Species can be real (as *Canis lupus*, for example) without being a "kind of kinds"—no rank of specificity. For the philosophically inclined, this lack of a universal definition of species implies that the category has no essential properties that all species must instantiate.

Finally, we need to treat organisms as organisms, not "kinds." Species **do** nothing, causally.[25] **Organisms** do the causal work in ecological terms. So we should divest ourselves of the notion that species are essential to understanding biodiversity and thus have innate value over and above the value of the organisms and populations that comprise them.[26]

5.8 Ramifications and Conclusions

Having a term and rank like *species* suggests a natural kind, a rank of living things, upon which we can anchor moral, political, and economic interests. Although our history suggests we often do not think all human beings are "fully" human in some fashion, human beings are the prototypical species. Humans (the **right** humans, that is) are not only *a* species, however, but we are *special* in some manner, using criteria that we choose such as tool use, language, technology, or the ability to reflect upon our experiences and selves. Darwin once noted in his Notebooks that if a bee were doing the evaluation, the ability to fly, fertilize flowers and make honey would be the criteria. Likewise, the extensive literature on "evolutionary transitions" based upon modes of information transfer (a human specialism) suggests that humans are somehow the peak of evolutionary progress. Whether or not we are at the top of a food chain, an evolutionary trajectory, or an ability to produce restaurant reviewers is irrelevant to the ways things are: we are one species among many species, and form one clade among many clades, one producer and consumer of ecological services among many… and so on. The anthropomorphism must stop. Interests are had by species incapable of any of these things, and we, for instance, cannot see in UV or fly unaided by culture.

This isn't the basis for an argument that other species have rights. They can be **given** rights, and I very much think that animals **should** have the rights and duty of care we assign to human children at the equivalent cognitive and emotional capacities.[27] Still, the point I am trying to bolster is instead that we should stop overexploiting other species for our interests, on the assumption that the Second

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[25] Inevitable exception: when a species consists of a causally cohesive population, then it does something, as a causally cohesive population (and not as a species).

[26] Other terms in biology, such as *lineage* or *populations*, and even *organism* have equally vague and plural meanings as well. That *species* and in general biological kinds are defined in these terms makes the point even more pointy. Thanks to Brent Mishler for bringing this to my attention.

[27] It is my view that rights are socially assigned on the bases of (the potential for) cognitive capacity and the ability to experience suffering. If this is the case, we can **choose** to assign rights to other organisms, based on the same potential and capacities.

Coming or if you prefer the Golden Age, if it occurs, is not likely to happen before we have done irreparable damage to the biosphere, at least in human terms.

Famously, Protagoras said that “man is the measure of all things,” although it is unclear precisely what he meant.[28] But at least in the period since the development of capitalism in the west, the tendency has been to treat the world as a reflection of human interests and capacities. This is anthropomorphism. It results from capitalist views of the natural world as being there for the benefit of and exploitation by humans. If species are not **all** “special” enough, we will lose on many current definitions of biodiversity. Religious-political beliefs must not take priority over the evidence that we must protect not all species but all ecological systems and processes as best we can. Others can say why species must have rights or why we have an Aldo Leopold-style land ethic; I just wish we did not focus fundamentally on a single category as a way to measure our economic and ethical concerns. Species are like labels in a shop: what they signify varies based on why they are labelled. Once we understand that, we must realize that we label ourselves and other species for our own purposes, folkways, and belief structures.

To summarise:

1. The species term and concept developed for non-scientific and scientific reasons, none of which support the reality of the species rank.
2. Like many other supposedly natural concepts (e.g., *wilderness*; Cronon 1996), *species* is defined according to our interests.
3. Species rights also reflect our interests.
4. So maybe we must stop the anthropomorphizing of living things and just try to preserve them. God knows it’s time.

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Chapter 6

Symbols and How We Came to Be Human

Mark W. Moffett

Abstract A longstanding belief commonly mentioned in support of human exceptionalism is that our species is distinct from others in using symbols (a word I use here, as it is in the social sciences, to describe anything with a socially shared meaning that isn't obvious). Countering the assumption that symbols are a distinct category that's unique to humans, I propose that they be properly recognized as operating in concert with an impressive number and diversity of less widely meaningful, or outright meaningless, social markers. This chapter critiques the views on symbolism in our species often expressed by sociologists, psychologists, anthropologists, archaeologists, and biologists. I consider how symbolism could have evolved from behaviors of non-human animals, some of which live in societies bound together by more superficial "markers" of identity that do not convey any more profound significance. Such markers, considered broadly, can be essential in holding societies together.

6.1 Introduction

People signal their identities in countless ways (Moffett 2013). We wear a ring to pronounce our commitment to marry, buy a Porsche to show off our wealth, don a chef's hat to let others know the job we do, and give credence to our patriotism as Americans when we stand proud before Lady Liberty. We go out of our way to imbue many such signals with a special symbolic weight through the kind of deliberate labeling that humans turn into an art.

Though "symbol" has come to be applied in other ways, for example, in computer science and psychoanalysis, I will use the word here, as social scientists and laypeople generally express it, to refer to anything with nonobvious meanings, and indeed with the usual requirement of multiple time-honored meanings, established by social convention through deliberate learning from others. A shamrock is at once a plant in the genus *Trifolium*, a means for predicting the weather, a good luck sign, a tool

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Saint Patrick used to teach the pagans about the Holy Trinity, and a symbol of the Irish and Ireland.

Much of the social sciences dwells on symbols and what they represent. For sociologists and many anthropologists, we structure our societies around a labyrinth of symbols that inform and guide our interactions: a bit of paper has worth as money, and a baptism cleanses us of sins (Blumer 1986). But while *Homo sapiens* truly is the symbolic animal, this does not mean symbols are all-encompassing. Symbols are not consistently meaningful or consequential. As I will show, they should be regarded as part of a far more extensive system of human signals and cues that indicate our commonalities with other species.

6.2 "Marking" Our Affiliations

A clue to how we came to be a symbolic species can be found in the fact that, while people transmit information with symbols, we also have ways of broadcasting our identities that are not intrinsically symbolic. Of course, we rely on signs that don't qualify as symbols. Some are icons that resemble their referents, like street signs with a crossed-out sketch of a person indicating *no pedestrians*. Other representations are understood through cultural conditioning without being explicitly taught: a bubble on a cartoon character's nostril, which a Westerner might associate with a runny nose, expresses sleepiness in Japan, something the comics researcher Neil Cohn believes the children there generally deduce on their own (Cohn 2013). Less talked about, however, are numerous traits that "mark" who we are yet lack any ordinary meanings that we can call to mind.

We may not be cognizant of these qualities in daily life, even when the differences are in plain sight. University of Georgetown psychologist Abigail Marsh determined that Americans can spot a fellow citizen with great success from subtle, subliminally acquired traits whose presence usually never reaches their conscious attention, including how he or she walks, waves a hand, or expresses feelings like irritation (despite the universality of human emotions, different societies display them in distinct ways). Tellingly, few people have the faintest notion they have this knack–or that they behave in this manner themselves (Ekman et al. 1987; Marsh et al. 2007, 2003).

Another category of largely subconscious signposts concerns the social standing of others, registered from how they dress to their posture and voice, mostly from cues that people are unlikely to put a finger on, let alone ascribe intricate cultural meanings to (Oh et al. 2020; Krämer et al. 2008).

Symbols are a subset of what I call markers, many of which are cues like a walking gait that carry little or no customary meaning. Some of these attributes go undetected until, perhaps, we are confronted by behaviors that run counter to our accepted practices; we don't observe what is unique about our cuisine until we are startled by the smell of exotic foods; or we realize the nature of our relation to time only when we visit a place where the populace is more punctual than we are or, conversely, likes to show up late (Hall 1959).

The combination of symbols and less overtly meaningful markers transforms our bodies into billboards pointing to who we are, from the styles of our hair to our footwear and toe rings and whether we shake our head or nod it (as Bulgarians habitually do) to say “no.”

Setting aside the way symbols work and where their power came from, it’s worth asking whether markers, broadly speaking, are exclusively human. Apparently, no. Animal signals such as the elephant’s excited trumpet can relate information about something other than themselves. A few of those signs are markers of identity; the humble ant, for one, differentiates its societies using the insectoid version of a national emblem, an aroma distributed across the colony membership. Learn and give off the correct odiferous sign, and each ant is golden, whether her colony is composed of ten individuals or ten million. Ants identify this colony scent when they reach adulthood and take it on themselves by grooming others (Tsutsui 2004). Social insect identities, distinguishing *us* from *them*, are marked by chemistry, plain and simple, an elementary yes/no reaction with no symbolic overtones added. A small minority of vertebrate animals similarly use a marker to set apart their societies, e.g., a scent in the naked mole rat and a sound in the sperm whale and certain birds (Moffett 2019a).

Of course, people are far more versatile in employing markers than ants. An ant’s “flag” usually changes little over her life, while her scent’s sole function is to designate membership. Our markers, on the other hand, whether profoundly significant symbols or unregistered in our awareness like our stride, can be modified over the years (think of the number of stars in an American flag) or serve other, at times, utilitarian functions (consider the rules about driving on the left or right side of the road); and some of them have nothing to do with distinguishing groups (a dove has become a universal symbol for “peace”).

What does our aptitude with such “marking” traits suggest about the origin of symbolism? The earliest markers didn’t need to designate anything obscure like good luck or connections to a deceased relative—they would simply have made our social categorizations unambiguous. Learning to control specific markers to communicate them deliberately, and incorporate symbolic qualities into them, could come about with time.

6.3 Making Sense of Our Actions

Even though our markers can be vastly more complex than the ant’s binding perfume, we need scant brainpower to recognize even the most Byzantine symbolic ones (Sterelny 2014). A dependable marker can potentially be given and understood by indefinite numbers of individuals with no additional cerebral demands and no obligation to sustain particular relationships (Moffett 2019b). Hence markers simplify life by making social interactions comfortably predictable. So long as unfamiliar persons look and act acceptable, ignorance is bliss: it's by dint of their personal billboards that ants and people allow strangers to coexist in a society.

By comparison, chimpanzees, who don't use markers to sort out who their comrades are, can't readily handle unknown others and must know each animal in their community as an individual. Imagine feeling obliged to introduce yourself to every stranger you meet or perpetually be aware of them as a possible threat. The demands would overwhelm. This fact, and not just human smarts, explains why chimpanzees occur in communities of at most about 200 while New Yorkers swarm by each other each day with hardly a concern (though the pandemic has been keeping them a bit farther apart than normal) (Moffett 2020).

Regardless of whether markers have scores of symbolic meanings or none that we can articulate, it's simplicity itself to detect them—even on each other, attuned as we are to the billboard each of us carries, from skin tones to the cross pendants on our throats. Humans register the physical, cultural, and other traits of those around us without a thought. We categorize anything we come across, including people as group members, reflexively, our positive or negative reactions triggered in milliseconds of an encounter. This occurs before we can put any loaded labels on them such as "working class," "faithful Christian," or "American." (Banaji and Greenwald 2013; Todorov 2017). The typical research subject is shown faces of different racial identities, but these automatic identifications, and responses, will hold as well for a simple abstract marker. So it is that Holocaust survivors needn't consider the symbolic implications of a swastika for the sight of one to engage the limbic system, setting off sensations of horror (Greenspan and Shanker 2009). National flags have grown so ubiquitous that on an average day we notice them barely more than the air we breathe, yet at some primal level we give them our attention. Yale psychologist Melissa Ferguson and colleagues found that a continual presence of American flags in the background intensifies people's sense of unity and nationalism (Butz 2009; Hassin et al. 2007).

Only when called on to explain ourselves afterward do we justify our conduct or emotions, often by spelling out what a marker imparts to us—in short, by crediting it with a symbolic value. Such research findings bring to mind views expressed by the 19th-century sociologist Vilfredo Pareto, who saw most behavior originating below the everyday awareness that we make sense of afterward via verbal accounts (Pareto 1935). Only at the stage of these rationalizations do we make full use of our cognitive powers, in part by dredging up the meanings we have been taught to associate with a particular situation, a predilection tracing back to when humans first tried to make sense of the attributes they held in common.

6.4 "Belonging" Isn't About Knowledge

I contend that our ancestors increasingly incorporated symbolic qualities into their markers and that we continue to build on such meanings to explain our shared behaviors. Actually, symbols are flimsy constructs since our rationalizations don't require their meanings to be deeply and consistently embedded in our thinking. As pointed out for people's knee-jerk revulsion to a swastika, a symbol doesn't need to be profound, or for that matter to possess a conventional meaning, let alone layered meanings, for us to be sensitive to it, or to its absence. The marker on its own, even if we are blind to its specific connotations, can give us an intense emotional ride. Americans well up with pride while fumbling through "The Star-Spangled Banner" without recalling its words or having the foggiest notion of what it is to be spangled. "It is likely that even people who are expert in the use of symbols—shamans, priests, or sorcerers—cannot state precisely what a particular symbol is all about," the anthropologist Mari Womack reminds us (Womack 2005, p. 51).

The less-than-obligatory importance of mutually understood meanings behind symbols is backed up by examples from my interest, which is in how societies hold together. Symbols like anthems are touchstones for patriotism. Yet to earn a passport, immigrants are taught more about the principles and emblems of the adopted country than native-born citizens, who are liable to think little about national symbols despite professing and insisting on devotion to them. No wonder most Americans would fail a U.S. naturalization test (Orgad 2011).

This reflects how in the normal course of life, we discern our compatriots less by their memory for facts than by their way of *being*: they act as expected, whether it's how they talk, gesture, or share social norms. We needn't burden our overloaded minds with the meanings behind every facet of our lives. Even if people agree about which markers excite their passions (Americans commemorating the 4th of July or honoring the U.S. Constitution), what message those cherished markers hold—if any—could well reside in the eye of each beholder. Such meaning could be based on his or her personal life experiences, rather than in what the general population makes of them, as a common symbol.

Even symbols with meanings that are widely recognized and well thought out evoke sentiments and memories specific to the different people and subgroups of people who value them. Thus, any commonalities the symbols suggest will mask a great deal of diversity, with those interpretations furthermore adapting over time to circumstances (Guibernau 1996). The pledge of allegiance represents something quite different to immigrant communities than anti-immigration activists, yet both revere this symbolic affirmation. While most symbols lodge in our collective memories long enough to give our lives a sense of stability, social cohesion can be imperiled when their meanings diverge so much that distinct social factions emerge within the same society. Consider the contrasting views about the statues of Confederate generals or even about donning a mask during the COVID-19 outbreak.

Once we acknowledge that ascribing standard meanings to symbols isn't the raison d'être of human life—that people do this poorly and yet still bond around all manner of social signals—the dawn of societies that allowed for the coexistence of strangers becomes easier to envision. After the long march of time tolerance of unfamiliar others with acceptable identities would come to undergird the burgeoning populations of modern nations.

To conclude that the meanings of the markers we call symbols are evoked after the fact, if even then, is not to claim that symbolism is insignificant. Most critically, at some point in our lineage we developed language, a symbolic mode of communication par excellence. (Although even there, children figure out most words from context and exposure, without being explicitly taught their meaning, as the usual definition of a symbol requires (Bloom 2001; Gopnik et al. 1999)). Exactly when language arose is a mystery, given that both gestures and the spoken word leave no trace. But speech has come to dominate our inner thoughts and outer lives, enhancing our capacity to think in the abstract and our ability to share an idea with many others, given a similar-enough interpretation of words. With language, a word like "hawk" can apply to its subject in complex referential ways. I might convey an idea such as hawks can fly even when no hawk is present or bring up the specific hawk you saw yesterday.

Through speech we exchange details about what we treasure; no wonder that the most adored aspects of our identities are the focus of everything from gossip to grand art. In fact, it's from such communications that we largely distill the meanings associated with the markers around us, etching them more or less the same way as symbols in every person's mind.

6.5 The Prehistory of Symbols—With a Warning

A commonplace assumption is that *Homo sapiens* has always wielded symbolic behavior, and perhaps earlier members of our family tree also did. It is no surprise then that carefully laid-out scratches on bone, eggshell pieces once likely strung into necklaces, and dyes that can be used to decorate human skin have been treated as evidence of early symbol-driven cultures[e.g., (Henshilwood and d'Errico 2011). Caution is in order, though. The hard truth is it might be impossible to ascertain at what juncture in the distant past people began to credit meanings to actions and things, and share the meanings amongst themselves as symbols. After all, we can embellish objects, wear jewelry, or paint ourselves just because such actions give us pleasure or furnish something we enjoy; colorful patterns go in and out of fashion on mass-produced goods merely because the novelty catches the eye for a time. Design elements like paisley endure the ages even though any meaning they were once endowed with is forgotten.

The trouble with analyzing the past is how easily we can assume the existence of symbolism. To wit, when children draw, they independently discover aesthetic geometric designs that can be surprisingly alike from child to child. Yet the similarities don't signal anything about the children's identities, let alone have an agreed-on meaning, as the Harvard psychologist Howard Gardner described in his 1980 book *Artful Scribbles* (Gardner 1980). And the meanings they do communicate, like mountains indicated by triangles, might not be arbitrary, as expected for a symbol, but rather show a figurative resemblance to what they stand for, and therefore denote something that a naïve viewer can guess. This applies as well to the intended impact of art. When asked to sketch a line to convey a feeling, adults from all over draw angles to express anger and curves to express positive emotions; uninformed others looking at the drawings describe the same sensations (Winner 2019). In a world of thorns and jagged rock, equating sharpness with a threat makes sense. This brings to mind how people everywhere intuit a dreamed lion as a sign of strength without being taught to do so—and consequentially, from the sociologist's point of view, it doesn't constitute a symbol (even if a therapist devoted to Freud's school of thought might say it is) (Stevens 1998).

Therefore, many recent human creations, let alone a prehistoric drawing of man or beast, didn't necessarily serve to illustrate something else, that is, act as a symbol for its people, no matter how elegant, abstract, or fanciful that masterpiece might be (e.g., Iliopoulos 2016; Malafouris 2008; Wynn et al. 2009). While sketching it out, or viewing it, doubtless engaged people's imaginations (Dutton 2009), a Paleolithic painting may simply represent a person; a human figure may have been given a bison head solely as a lark; red body paint could have been beloved for no reason other than that it was pretty. Indeed, Griffith University anthropologist Michelle Langley has proposed that much of what we think of as Paleolithic art may have been devised in play, perhaps for children (Langley 2018).

Discussions of symbolism in archaeology are seldom more than hunches that unearthed artifacts *might* have stood for something and, for all we know, are more of a measure of how symbol-obsessed we are today than an accurate appraisal of our predecessors. Such reports often point to records of living hunter-gatherers doing things like painting a tribal motif with red ochre crayons; or to a repetition of art over generations, or across widely spaced locations, implying at least an abiding aesthetic preference—or perhaps an outcome of what University of Sydney archaeologist Peter Hiscock calls the echo principle. Paleolithic people would rediscover older stenciled handprints or bison paintings, and in all likelihood replicate them much as a college student will copy a Monet. Never losing sight of their forefathers' practical or aesthetic designs, humans kept returning to them, echoing the past (Hiscock 2007). Whether those recurrent designs originally symbolized something is beyond reckoning. Still, a commonsensical hypothesis would be that among the first artifacts to which people put symbolic meanings were objects their forebears had already delighted in for generations—among the items people brought into caves between 195,000 and 123,000 years ago were the sorts of pretty seashells we are still fond of collecting (Marean 2010).

Few have disputed that certain relics held well-established meanings to their makers. Burial of the deceased, which began at least 100,000 years ago in *Homo sapiens* and was done by Neanderthals, too, suggests a mourning process now richly symbolic (Zilhão et al. 2016). Yet around the globe, depending on the person and the situation, human corpses can be disposed of for reasons other than as a mortuary ritual: feeling disgust around rotting flesh for one. Objects carefully interred with the dead are another matter. Ochre, found near some ancient remains, might have meant something to the living. Less open to question are the clothes of two children buried near Moscow 30 millennia ago, adorned with thousands of ivory beads that must have taken years, and great motivating force, to produce—evidence of the spiritual significance of their death, their high social rank or both (Trinkaus et al. 2014).

But even a clue of someone's importance needn't be associated with a widespread symbolic meaning.

All this is to say that because the meanings of symbols are by definition not obvious to the eye, ascribing symbolic importance to artifacts from the remote past can be wishful thinking, despite the bold assertions that have often been made about archeological findings.

6.6 The Origins of Markers and, Eventually, Symbols

Nowadays people are inspired by so many symbols with common meanings accrued over centuries that it's a struggle to imagine some proto-human population with no idea-laden symbols at all. Acknowledging that the construal of prehistoric artifacts as symbols will always be a debatable business, we must nevertheless ask how people first came to have markers, let alone deeply appreciated symbolic ones?

Underlying the evolution of our first social markers may have been an urge to match others. Our predecessors would have excelled at learning from each other, an ability in reach of some animals; consider the novel song that swept across Canadian populations of white throated sparrows over the last 20 years (Otter et al. 2020). This talent can generate cultures, that is, the sum total of socially transmitted information, including such traditions as exist in meerkat clans that prefer to sleep late or chimpanzees that pick rocks versus sticks to open tasty nuts (Whiten and Schaik 2007).

While languages enable us to combine symbols in complex ways, symbols, or at least their rudimentary antecedents, could have materialized prior to speech, as is intimated by what some monkeys accomplish. Certain species give different vocalizations to warn of danger, depending, in the case of vervets, on whether the threat is a snake, a hawk, or a leopard. The primates respond to the calls as if they had seen the predator themselves, for instance, strategically descending to earth should they be in a tree or hiding in a bush if they are on the ground after hearing an eagle alarm. Moreover, while the calls vary little from troop to troop, the vervets learn from their fellow troop members which snake, bird of prey, and predatory mammal species the sounds apply to locally, and prefer to cry out when their friends or family happen to be in earshot (Cheney and Seyfarth 2008).

Monkey vocalizations are of restricted utility: a vervet can't describe a hawk seen yesterday or point out that hawks fly, as we can with language. That's because no matter how smart the animal, a signal like a hawk call given on its own isn't likely to convey such details. Whatever's going on in the monkey mind, lacking a method for combining words, as people do, to the nth degree, with language, it can just express what's happening in the here and now (contrast that to a person shaking her head when uttering the word hawk to say no hawk is around). More generally, rather than an utterance symbolizing something, vervets may be responding to the sounds of a troopmate as a matter of simple association: they learn to connect a particular cry to a snake being present much the same way they connect lightning with thunder. In fact, in the view of University of California anthropologist Terrence Deacon, nothing should be designated a symbol that exists in isolation. He argues that symbols must exist in combination with other symbols as part of a system (Deacon 1997).

There's evidence that various animals have some capacity to use symbols even in this restrictive sense. In her years of studying parrots, ethologist Irene Pepperberg has shown that tame birds can put together words they memorized, providing insights into their comprehension of what's being communicated (Pepperberg and Call 2017). And one monkey species is known to do this in nature, with sequences of calls that both point out a predator and indicate how much of a hazard it represents at the moment (Arnold and Zuberbühler 2006).

As for chimpanzees, while I've already mentioned these apes don't pick out comrades based on any sort of identifying marker, that isn't to say they lack anything we can think of as symbolic. As it happens, the behaviors they master by observing one another connote distinct things in different communities. A chimpanzee's vocal cords generate only a limited array of sounds; it makes sense for this species to rely heavily on arbitrary actions or gestures, often after the communicator makes sure the desired individual or group is watching (Pollick and Waal 2007; Bard et al. 2017; Pika and Fröhlich 2019).

For instance, noisily tearing foliage with the teeth is given as an invitation for sex in one community, for play in another, and for aggression in a third. Meanwhile, in a community where ripping twigs denotes something else, willingness to play can be signaled by making nests on the ground. (Boesch and Valsiner 2012) More is going on than mere association. To get the message across, a nest-maker can repeat the act until its persistence pays off while adding a "play face," smile, or other signs of wanting to frolic, indicators of intentional communication (Andrews 2020; Waal et al. 2012).

In addition to using languages, what people do that no other primate does is take the step of connecting such cultural signs with their societies, in extreme cases rejecting those who act inappropriately, say by disrespecting the flag. A chimpanzee loudly chomping greenery for the "wrong" reason isn't attacked for this act since the apes don't perceive the behavior as indicative of belonging to their community (Gruber et al. 2015). Still, we can imagine that at least one highly variable chimpanzee call, the pant-hoot, could readily evolve to serve this purpose, if the members of each group were able to learn a particular pant hoot from one another to create community dialects (as was once thought likely, and still might be the case in some populations: Desai et al. 2021).

A signal to which our forebears responded in this way could have been the precursor of our symbols, for example, if they gave it as a greeting (Tsutsui 2004). Such a primal marker would represent a kind of password that we duplicated from one another, which at first needn't have been more meaningful than an ant's home scent. This protoword for *us* would have become interlinked over time with other group differences of the sort found in chimpanzees, as these started to be used a identity markers as well, thereby creating a prototype of the billboards that proclaim human affiliations. The evolution of this transformative attribute of human identification with groups likely initiated our symbolic existence.

6.7 The Human Relationship to Symbols

I have examined symbols from the perspective of a range of disciplines to conclude that much of the human universe is *not* mediated by symbols per se but rather by simpler, at times subconscious markers of the general sort found in some other species. Our initial markers would have served to reinforce categories of social significance to early humans, notably to the societies that those markers helped keep intact; from such markers would have emerged the first human symbols—indeed, entire systems of symbols.

What does all this intimate for people and their potent relationship with symbols? Tool making lost its privileged status as a defining trait for humans after other species, notably our chimpanzee relatives, were seen modifying objects to carry out such tasks as collecting termites with a stick or mopping water using crushed foliage as a sponge (Sanz et al. 2013). Self-awareness was believed to separate people from animals, too, but we have since learned that chimps, dolphins, and elephants recognize themselves in their mirrored reflections (Reiss et al. 2017). Symbol making similarly falls short as a trait elevating us above "the animals" (Heyes and Frith 2014; Grice 1989).[1]

That said, humans undeniably take the employment of symbols to extremes. Much as our increasingly complicated tools have come to play a role in nearly all our activities and our self-awareness now influences every human relationship, our symbols have likewise grown in sophistication and importance, with languages ultimately bringing to bear vast numbers of interconnected symbols that relate to matters beyond the here and now. The payoffs for turning just about anything into a symbol were likely amplified as our comprehension of the state of mind of others improved, making it possible for us to wittingly express who we are in our interactions with individuals or groups (Tomasello 2014). An outcome of this collective mastery of meaning is it opened up higher levels of reasoning about our relationships to the world (Penn et al. 2008), and a reassuring sense that life is predictable and meaningful (Baumeister and Hippel 2020).

Symbols, however, should be properly recognized as operating in concert with a striking diversity of less broadly meaningful, or outright meaningless, social markers (Tsutsui 2004). All told, these cultural guideposts constitute the intricate web that sociology rightly depicts as the core of the human way of life, contributing vastly to the richness of our experience.

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[1] A currently favored criterion for human distinctiveness is a grasp of each other's mental states so refined we readily decipher the intentions and goals of our fellows and overtly express our intentions to them, such that we not only communicate what we wish but express our desire to convey that idea (e.g., Heyes and Frith 2014, Grice 1989).

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Part III
Conservation and Law

Chapter 7
Law and Nature: Human, Non-human, and Ecosystem Rights

Gary Steiner and Marc Lucht

Abstract The major exponents of the Western philosophical tradition have long maintained a conception of rights according to which only human beings can be possessors of rights. On this view, it makes little or no sense to attribute rights to sentient non-human beings, and it makes no sense whatsoever to attribute rights to non-sentient nature. A reflection on the basic commitments motivating this conception of rights reveals that it is based not on robust rational considerations but rather on the unargued anthropocentric prejudice that specifically human forms of rationality are required for full moral status. The tradition's focus on logos leads many exponents of the tradition to exclude non-human animals from the sphere of justice altogether. Recent work in philosophy and ethology, however, has shed light on the intelligence and emotional lives of many non-human animals, and has made it necessary to rethink the moral status of non-human animals. Even more radically, environmental philosophers argue that rejecting anthropocentrism opens the door to the recognition that some even non-sentient and non-living natural phenomena deserve moral consideration and bear rights that ought to be respected. The substantial conceptual differences between ecocentrism and the animal rights approach focus attention on fundamental questions about the very conditions for moral worth and highlight our need for a more satisfactory theory of the world and the proper place of humanity within it.

7.1 The Idea of Rights for Non-human Beings

As heirs to a tradition of Western thinking that dates to the ancient Greeks, we are deeply inured to a system of values according to which the notion of rights properly applies only to human beings. This way of thinking and valuing is so deeply

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entrenched in our understanding of ourselves and the world that it is extremely difficult to establish the critical distance necessary to take seriously the question whether it might make sense to attribute rights to non-human beings such as animals, and it is especially difficult to contemplate the proposition that non-sentient living beings such as trees or ecosystems might have rights.[1] After all, is it not the case that it would be nonsensical to attribute rights to an entity such as a tree, which seems utterly incapable of any kind of subjective awareness and hence unable to avail itself of any rights it might possess?

From the standpoint of over two thousand years of entrenched common sense, such a proposition is absurd. But for all that, it is not clear that the idea of rights for non-human beings, sentient or otherwise, is ill-conceived. In the present discussion, we set aside the question of rights for non-living beings and focus our attention on the question of rights for living beings, both sentient and non-sentient. We begin by retracing the steps of the history of thinking that has left many in our culture unable and unwilling to take seriously the idea that beings other than humans possess rights. An examination of this history reveals that the idea that rights are exclusively human is based on a fundamental, insufficiently interrogated prejudice about the place of human beings in the cosmic scheme, a prejudice that arrogates the status of divinity (or quasi-divinity) to human beings and relegates all non-human beings to the status of instrumentalities for the satisfaction of human needs and desires.

A reflection on the status of this conviction as a prejudice rather than a product of rational reflection opens up the prospect of challenging it as arbitrary and self-serving, and in turn this opens up the prospect of thinking in a more objective manner about the notion of rights, the sorts of beings to whom or which it properly applies, and the tasks that such a rethinking leaves us for finding a more authentic and morally legitimate relationship to the rest of nature. For the epic excesses and transgressions we have committed against non-human nature, both sentient and non-sentient, cannot be adequately grasped and ameliorated unless and until we arrive at a more *modest* sense of the natural world and our proper place in it.

The history of thinking that we examine here has come in recent years to be characterized as "anthropocentric" in the sense that it proclaims a sense of human centrality and supremacy in the natural order. The idea, for example, that the natural world was created expressly for the sake of human beings—an idea urged by ancient Greek and medieval Christian thinkers alike—is anthropocentric in the sense that it gives human beings license to use everything non-human in the world as resources, without any moral scruple whatsoever other than a concern for the effects our actions may have on other human beings.[2] And while one might think that we moderns are sufficiently enlightened to have shed the irrational prejudices of our ancient and

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[1] One could push this line of questioning even further and raise the question whether some non-living beings, such as works of art, might be said to possess rights. See for example Lemos (1982).

[2] It may be worth considering whether the term "anthroposupremacist" better characterizes this attitude than does the more commonly used "anthropocentric."

medieval forbears, the modern scientific reduction of nature to a nexus of efficient-causal relationships operating on inert matter has actually intensified the exploitation of non-human nature to the point that, in Heidegger's words, we have reduced nature to "a gigantic gasoline station, an energy source for modern technology and industry."[3] And, as will become clear in the following discussion, Heidegger's words apply not only to our treatment of non-sentient nature but also, and with great force, to our treatment of non-human animals.

We examine the history of anthropocentric thinking as it applies to our culture's conceptualization and moral valuation of non-human animals, and then we turn to the question whether it might make sense to attribute rights to non-sentient nature. We conclude with some programmatic suggestions about how we would have to rethink the idea of the natural world and our place in it, if we are to reverse the course of an extremely long history of treating non-human beings as beings without inherent worth—a history that has left us with a global crisis we are currently ill-equipped to address, not only because of technological limitations but more importantly because of limitations on our *thinking* imposed by long-standing anthropocentric prejudice.

7.2 Animal Rights

7.2.1 The Problem of Speciesism

Let us imagine a world in which sex slavery is widespread—a world in which girls and young women are customarily and forcibly confined in squalid conditions and their bodies repeatedly violated by men with power over them, a world in which such treatment has the status of normality and few if any onlookers express the slightest misgivings about this regime of domination and submission. And let us imagine that a few self-styled crusaders came forth and insist that the rest of us acknowledge that a grievous injustice is being perpetrated. But what if, instead of maintaining that the only just solution to the problem is to abolish sex slavery altogether, these critics launch a campaign to get more comfortable beds and good medical care for the imprisoned sex slaves? What would be our reaction to such a proposal? One can only assume that a great many people would be astonished, that they would take such a proposal to be cavalier and inhuman, and that they would reply without hesitation that the only just response to such a practice would be to seek its categorical abolition.

Now imagine a world in which the flagrant exploitation of non-human animals is widespread—a world in which a wide variety of animals are customarily and forcibly confined in squalid conditions, their bodies repeatedly and constantly violated by human beings with power over them, a world in which animals are taken for granted by almost the entire human race as little more than delivery devices for food, clothing, entertainment, scientific knowledge, and labor, a world in which in almost all cases

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[3] Heidegger (1966).

we end up killing the animals under our control. And let us again imagine that a few wild-haired nay-sayers come forth and decry these practices as unjust exploitation. And, as in the sex slavery case, these critics call for more comfortable living conditions for the exploited beings, rather than calling for the abolition of the regime of exploitation. It is here that the two hypothetical cases, neither of which is entirely hypothetical, diverge. For in the case of human exploitation and degradation, most if not all of us find the prospect of improved conditions for sex slaves to be an inadequate response to a tragic problem, while in the case of animal exploitation the prospect of marginally less traumatic living conditions for animals on the way to their deaths enables us to slumber peacefully—if, indeed, we were bothered by the regime of animal exploitation in the first place. Consider in this connection the passing of Proposition 2 in California in November 2008, a measure that called for marginally less deplorable living conditions for animals destined for slaughter and human consumption.

It is hard to imagine a ballot measure that would call for more comfortable beds and proper medical care for sex slaves. But Proposition 2 was passed by a two-thirds majority of the voting public. It is tempting to suppose that the passage of Proposition 2 reflects increasing concern on the part of humanity about the fortunes of the animals we kill and consume. But how much genuine concern can we be said to have for sentient beings that we are completely comfortable with confining, killing, and consuming? The fact that the same voting public that passed Proposition 2 would consider abhorrent an initiative to provide better living conditions for sex slaves reflects radically different sensibilities about the moral status of human beings and non-human animals. What are the nature of, and the basis for, our different sensibilities about animals and our fellow human beings? Even a brief reflection on the history of Western thinking about human beings and animals shows that these sensibilities reflect deep-seated prejudices about the moral superiority of human beings over animals. One of the most fascinating features of these historical prejudices is that they incorporate just enough truth to conceal the unjustifiable speciesism, the arbitrary privileging of human beings over all other species, that lies at their core.

7.2.2 The Historical Roots of Contemporary Speciesism

The origin and gathering focus of our historical sensibilities is the proclamation of Aristotle and the Stoic philosophers that only human beings possess *logos* and that all non-human animals are categorically *aloga*, lacking in reason or language.[4] For Aristotle, a being must possess rational capacity in order to qualify as a member of a political community. Possessing rational soul, human beings can "set forth the expedient and the inexpedient, and therefore likewise the just and the unjust." Rational

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[4] For specific details of the views of Aristotle and the Stoics, see Steiner (2005), Chap. 3.

capacity also enables human beings to have a “sense of good and evil.”[5] Beings lacking *logos* are, on the view advanced by Aristotle in his psychological, ethical, and political treatises, bereft of these capacities and thus have no place whatsoever in political community with humans. Aristotle was intimately familiar with a wide variety of forms of animal behavior, having written a number of texts on animals. And while he sometimes acknowledges in his zoological treatises that many animals exhibit intelligence and ingenuity, in his psychological, ethical, and political texts he stresses the fundamental *differences* between human beings and animals and characterizes animal behavior as being driven deterministically by bodily desires. Thus while he acknowledges that many animals live in communities, in the *Politics* Aristotle maintains that “man is more of a political animal than bees or any other gregarious animals.”[6] This “more” consists in the fact that human beings can contemplate different possible courses of action, can form general principles, and, most importantly, can devote their lives to the pursuit of moral virtue. It is ultimately our capacity for deliberative choice (*proairesis*) that makes all these activities possible, and it is the fact that animals are driven entirely by bodily desire (*thymos* and *epithymia*) that renders them fundamentally incapable of moral virtue and hence of membership in anything like a moral or political community with human beings.[7] To this extent, our ethical and political obligations to animals are no different than to a “slave *qua* slave:” Slaves, like animals, are “living tools,” and as such “there is nothing common [*koinon*] to” freemen and their chattel. At the same time, even though one cannot have a friendship or a justice relationship with a slave *qua* slave, it is possible to have a friendship or justice relationship with a slave *qua* man, whereas there is no more possibility of having a friendship or a justice obligation toward an animal than there is “towards lifeless things.”[8]

The Stoic philosophers elevate this sense of human exceptionalism to the status of a cosmic principle, articulating a worldview according to which all sublunary non-human beings were created expressly for the sake of satisfying human needs. Like Aristotle, the Stoics appeal to certain cognitive differences between human beings and animals, and in particular the Stoics argue that animals lack the capacity for rationally-structured mental and emotional states.[9] This leaves animals incapable of “wisdom, foresight, diligence, and reflection,” which “have been granted to no creature but man.”[10] From this, Seneca draws the conclusion that animals are locked in an eternal present, and that “the Good…does not exist in dumb animals” because

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[5] Aristotle, *Politics*, book 1, Chap. 2 at 1253a14-16, *The Complete Works of Aristotle*, 2 vols., ed. Jonathan Barnes, Princeton: Princeton/Bollingen, 1995, vol. 2, p. 1988.

[6] Aristotle, *Politics*, book 1, Chap. 2 at 1253a8-9, *The Complete Works of Aristotle*, vol. 2, p. 1988.

[7] Aristotle, *Nicomachean Ethics*, book 6, Chap. 2 at 1139a21-25 and 32, *The Complete Works of Aristotle*, vol. 2, p. 1798; *Eudemian Ethics*, book 2, Chap. 10 at 1225b26-7, *The Complete Works of Aristotle*, vol. 2, p. 1941; *Nicomachean Ethics*, book 3, Chap. 8 at 1116b24-1117a5, *The Complete Works of Aristotle*, vol. 2, p. 1763.

[8] Aristotle, *Nicomachean Ethics*, book 8, Chap. 11 at 1161b1-5, *The Complete Works of Aristotle*, vol. 2, p. 1835.

[9] Laertius (2000), 7.55, 7.63, and 7.111, pp. 165, 173, 217.

[10] Seneca (1928).

"it is a matter of the understanding [*intellectus*]."[11] To say that the good "does not exist" in animals does not mean that they cannot fare well or ill, but rather that the good for animals consists simply in material welfare; the good is absent in animals in the sense they cannot contemplate the good as such. Humans, on the other hand, stand in proximity to the gods in being capable of rationally contemplating the divine *logos*, the ideal order of the cosmos.[12]

On the Stoic view, all beings incapable of contemplating the *logos* exist to satisfy the material needs of human beings—the logic being that, as Aristotle had recognized, the leisure to contemplate demands that our material needs have been satisfied.[13] The capacity to engage in pure contemplation, Aristotelian *theoria*, not only distinguishes human beings from non-human animals, but also makes us most like the gods, who engage in nothing but contemplation. And while this view of the respective places of human beings and animals in the cosmic order might outwardly appear to be identical with Aristotle's view that plants exist for the sake of animals and animals for the sake of man, in fact the Stoics elevate what is a tentative statement of prevailing common sense into a cosmic principle.[14] There is an essential cosmic order, with gods at the apex, humans in relatively close proximity to the gods, and all other sublunary beings existing to satisfy the material needs of those beings capable of contemplation that stand in need of material sustenance.[15]

These commitments implicitly inform the entire subsequent history of Western thinking about the notion of rights and particularly about who properly counts as a possessor of rights. The Stoic position regarding the sphere of right finds a clear focal point in the doctrine of *oikeiosis*, a doctrine of belonging or membership. The Stoics, like Aristotle, recognize that many animals share in something approximating community; but the Stoics follow Aristotle in maintaining that there is "nothing common [*koinon*]" between human beings and animals in an ethically or politically relevant sense. The Stoics, like Aristotle, exclude animals from community with human beings on the grounds that animals are governed by impulse rather than by reason. Marcus Aurelius goes so far as to assert that community [*koinoia*] in a strict sense is not just any assemblage of living or sentient beings but specifically "the good of a rational being."[16] The Stoic conception of *oikeiosis* makes it clear how thinkers such as Marcus Aurelius arrive at the conclusion that community in the highest sense categorically excludes animals. The Stoics conceive of *oikeiosis* in terms of

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[11] Seneca (1925), 124.16–18, 124.1–2, pp. 445, 437.

[12] Seneca (2000), p. 43; Cicero (1999), p. 239.

[13] Cicero (1990), 54H; see also Epictetus, *Discourses* 1.6.18, 1.16.1–5, and 2.8.6–8.

[14] Aristotle, *Politics*, book 1, Chap. 8 at 1256b14-21; Seneca (1930), 76.11, p. 153; see also White (1979): 175.

[15] Cicero, *On the Nature of the Gods* 2.133, *The Hellenistic Philosophers* 54N. It is easy to overlook the vital role played by animals in satisfying human needs, inasmuch as the Stoics classify animals along with other material things as *adiaphora* or "indifferents;" in this connection it is important to note that the Stoics qualify this classification by considering animals *proegmena* or "preferreds." See Diogenes Laertius, *Lives of the Eminent Philosophers*, 7.105, vol. 2, p. 211 and Cicero, *On Ends*, 3.15.50–51, pp. 269–71.

[16] Marcus Aurelius 5.16, *The Hellenistic Philosophers* 63 K.

ever-wider spheres or circles of belonging.[17] The first stage of *oikeiosis* is a being's sense of attachment to its own body and its affinity for those things that conduce to material welfare. The second stage of *oikeiosis* is a being's sense of attachment to members of its immediate family, particularly to its offspring. Humans and animals alike are capable of these first two stages of *oikeiosis*, whereas only human beings are capable of making the move to the third stage. At the third stage of *oikeiosis*, rational reflection facilitates "the association of the human race in communities" and makes possible the unification "of the whole human race."[18]

At this most encompassing stage of *oikeiosis*, a sense of concern for all of humanity, even for complete strangers, becomes possible. "The mere fact of their humanity requires that one man should feel another man to be akin to him."[19] This rationally-informed sense of kinship is the ground for "society and intercourse, and for a natural partnership with our fellow men. Moreover nature inspires us with the desire to benefit as many people as we can, and especially by imparting information and the principles of wisdom."[20] The Stoic sense of kinship among humans forms the historical background of the modern conception of the sphere of right, one according to which human beings are included and animals fundamentally excluded: Community in the authentic sense admits only those beings capable of reciprocal acknowledgment and the shared pursuit of moral virtue; thus nonrational beings, beings that are aloga, are categorically excluded from the sphere of right. "It is [the Stoic] doctrine that there can be no question of right [*dikaion*] as between man and the lower animals, because of their unlikeness."[21] In virtue of this lack of kinship, "men can make use of beasts for their own purposes without injustice."[22]

In antiquity, the Aristotelian-Stoic exclusion of animals from the sphere of right on the grounds that they are *aloga* finds its complement in Epicurus's contractualist approach to the notion of justice. Like Aristotle and the Stoics, Epicurus links membership in the sphere of justice to the capacity to "reflect on the things themselves."[23] Epicurus's account of justice closely follows the terms of Aristotle's association of justice with expediency; for Epicurus, justice functions "to prevent one man from being harmed by another."[24] This account of justice also closely follows the terms of the notion of justice that figures centrally in the "golden age" story told by Hesiod and retold by Ovid, a story according to which relations among human beings as well as between human beings and non-human animals were initially peaceful but

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[17] For a more detailed discussion of *oikeiosis*, see Steiner, *Anthropocentrism and Its Discontents: The Moral Status of Animals in the History of Western Philosophy*, pp. 88–92.

[18] Cicero, *On Ends* 3.62–3, p. 283; Hierocles (Stobaeus 4.671.7–673.11), *The Hellenistic Philosophers* 57G.

[19] Cicero, *On Ends*, 3.63, p. 283.

[20] Cicero, *On Ends* 3.65, p. 285–6.

[21] Diogenes Laertius 7.129, p. 233 (referring to the views of Chrysippus and Posidonius).

[22] Cicero, *On Ends* 3.67, p. 287 (describing Chrysippus's view).

[23] Diogenes Laertius 10.18, p. 669.

[24] Diogenes Laertius 10.31, p. 675.

eventually devolved into violence.[25] When humanity finally became violent, Zeus had to come to earth and impose the law of justice (*dike*) on human beings as a means for preserving peace and order. Animals were excluded from the justice bond on the grounds that they could not "listen to justice," i.e., on the grounds that they were *aloga*.[26] Epicurus frames this idea in what have come to be known as "contractualist" terms: only those beings capable "of making covenants with one another, to the end that they may neither inflict nor suffer harm," can properly be said to participate in the sphere of justice.[27] Even though Epicurus at one point calls this conception of justice "natural," he denies that there is such a thing as "absolute justice" and maintains that justice consists in nothing more than "an agreement made in reciprocal intercourse…against the infliction or suffering of harm."[28]

Thus membership in the sphere of justice once again devolves upon rational and linguistic capacity, in this case the capacity to enter into mutually-binding reciprocal agreements pertaining to non-harm. Epicurus is clear that the terms "justice" and "injustice" have no application to beings that are incapable of contracting for peaceful interrelationships. Does this by itself show that animals are categorically excluded from the sphere of justice, such that nothing we do to a non-human animal can possibly be considered an injustice? Epicurus does not go so far as to proclaim that only human beings can participate in justice relations, but his remark about the importance of reflecting on the things themselves and his emphasis on the ability to enter into contracts tend strongly in this direction. Porphyry, for one, concludes that Epicurus denied animals the capacity to enter into contracts on the grounds that they "are not receptive to reason."[29]

At the same time, one can reasonably ask the question whether an Epicurean account of justice can accommodate the proposition that at least some animals should be included in it. Do some animals enter into agreements, either with one another or with human beings? The question of justice relations among animals is not of immediate concern in the present discussion, inasmuch as the central question here is whether it makes sense for human beings to recognize rights in animals that create corresponding obligations in human beings. Of more immediate relevance is the question whether it makes sense to see human-animal relations in the contractual terms sketched by Epicurus. One answer that has been given to this question is found in Lucretius: that domesticated animals, at least, "have eagerly fled from the wild beasts, they have sought peace and the generous provision gained by no labour of theirs, which we give them as the reward of their usefulness."[30] In other words, domesticated animals accept the conditions of domestication in at least quasi-contractual exchange for the protection from wild animals provided by human beings.

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[25] See Steiner, *Anthropocentrism and Its Discontents: The Moral Status of Animals in the History of Western Philosophy*, pp. 43–5.

[26] See Hesiod, *Works and Days* 207–13, 275; see also Ovid, *Metamorphoses*, book 1, lines 90–162.

[27] Diogenes Laertius 10.32, p. 675.

[28] Diogenes Laertius 10.31, 10.33, pp. 673, 675.

[29] Porphyry (2000), 1.12, p. 36.

[30] Lucretius (1997), 5.868–70, p. 447.

Whether this line of reasoning makes sense depends not only on whether one considers animals to be sufficiently rational to enter into mutually-binding agreements, but also on whether one considers domestication to be truly beneficial to animals or instead considers it to be part of a regime of human dominance over non-human nature that ultimately benefits only humans. With regard to both considerations, it is worth bearing in mind that for the most part we treat animals exactly as our ancient predecessors had, namely, as *aloga*, so it seems peculiarly convenient to let ourselves believe that these animals possess rational capacity just enough to give their consent to be husbanded by human beings even though they lack rationality with respect to all other life contingencies. The sense that there is a self-serving inconsistency at work here is only heightened by the most elementary reflections on the ways in which animals are treated under the regime of domestication.[31] In this connection it would be productive to consider the analogous question whether it makes sense to suppose that a group of dependent human slaves might consider themselves similarly bound by an agreement with free humans to provide compulsory service in exchange for protection from "wild" threats, particularly in light of the fact that thinkers such as Aristotle have argued that those human beings who count as "natural" slaves are incapable of articulating rational principles for themselves but must depend on other, more rational human beings to do this on their behalf.[32]

Even more fundamental in this connection is the question whether the very idea of rights is properly understood as a set of reciprocal agreements of non-harm, or whether this conception of rights misses what justice means at its most foundational level. The idea of rights understood as reciprocal agreements presupposes that justice is a *quid pro quo*, that justice is ultimately a matter of extending consideration to others simply because one expects to get something in return. But justice is more than simply a matter of expediency, as should be evident from even the most elementary reflection on the fact that one can wrong another even in the absence of anything like a mutual agreement of non-harm. One thinks immediately in this connection of Kant's example of the shopkeeper who contemplates cheating a young child: The ultimate wrongness of cheating the child has nothing to do with expediency and everything to do with respecting the child's personhood.[33] Kant himself would never consider extending the principle of respect to non-human animals, inasmuch as he categorically classifies animals as "things," which are mere means, in contrast with "persons," which are the only proper objects of respect.[34]

This refusal on Kant's part brings into focus a question that neither he nor his predecessors in antiquity ever confronted, namely, why a being must necessarily

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[31] For a revealing reflection on the nature and effects of domestication, see Nibert (2013).

[32] See Aristotle, *Politics*, book 1, chap. 13 at 1260a13-14, *The Complete Works of Aristotle*, vol. 2, p. 1999: "For the slave has no deliberative faculty at all."

[33] Kant (1981), p. 10 (Ak. 397). Here Kant does not specify a child but instead "an inexperienced purchaser."

[34] Kant (1997), p. 147.

possess *logos* in the specifically human sense of abstract rationality and predicatively-structured language in order to count as an object of respect.[35] There have been a few thinkers, such as Porphyry in the early Middle Ages and Schopenhauer in modernity, who have challenged this prejudice and have expressed a much greater openness to the proposition that mere sentience is sufficient for inclusion in the sphere of justice. Schopenhauer, for example, situates human or "temporal" justice within the larger framework of "eternal" or cosmic justice, just as in the twentieth century Karl Löwith would situate human politics within a more encompassing "cosmopolitics."[36] It is within this larger context that it first becomes intelligible to speak of injustices toward non-human animals.

For Aristotle, the Stoics, and Epicurus, a being must be rational and linguistic in order not only to be capable of active participation in the sphere of justice, but to *merit inclusion* in the sphere of justice. For these thinkers, as for a line of thinkers that extends through Augustine, Aquinas, Descartes, and Kant up to contemporary thinkers such as John Rawls and John Finnis, being a beneficiary of justice is an all-or-nothing affair: If a being is a moral agent and can take on duties of justice toward others, then that being is entitled to moral consideration and possesses rights. But if that being lacks the capacity to contemplate and respect rights and duties, then that being is excluded from the sphere of right altogether and nothing we do to that being can be construed as an injustice. And to the extent that animals are *aloga* and can neither contemplate nor act in observance of rights and duties, for these thinkers we have no justice relationship with animals whatsoever. Any concern we express toward animals is either a matter of personal inclination or a by-product of our concern for our fellow human beings.

This line of thinking persists virtually unmodified in the entire subsequent history of Western philosophy. Saint Augustine writes that "we can perceive by their cries that animals die in pain, although we make little of this since the beast, lacking a rational soul, is not related to us by a common nature."[37] Saint Thomas Aquinas asserts that animals are moved purely by instinct and entirely lack cognition, that animals are completely lacking in free will, and that because "by divine providence [animals] are intended for man's use according to the order of nature…it is not wrong for man to make use of [animals], either by killing or by any other way whatsoever." Aquinas's only qualification on this last statement is that we ought to avoid inflicting gratuitous harm on animals—not because we owe anything to animals, but because such infliction of harm makes us more liable to be cruel to our fellow human beings.[38]

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[35] Christine Korsgaard has recently sought to revise Kant' views on animals on exactly this basis, although she retains Kant's commitment to the idea that human beings are distinct from animals in possessing rationality. See Korsgaard (2018) (suggesting at p. 97 that it is "likely that only human beings are rational").

[36] See Arthur Schopenhauer (1995), sec. 17, p. 152 and (1958), sec. 63 and 64, pp. 350, 357; Löwith (1981), p. 303. On the notion of cosmic justice, see also Steiner (2008), Chaps. 5 and 6.

[37] Augustine (1966), book 2, Chap. 17, sec. 59, p. 105.

[38] Saint Thomas Aquinas, *Summa Theologica* 1–2, q. 40, art. 3, repl. obj. 1, in *The "Summa Theologica" of St. Thomas Aquinas*, trans. Fathers of the English Dominican Province, 22 vols. (London: Burns Oats and Washbourne, 1920–25), 6:460; *De Veritate*, q. 24, art. 1, resp., in *Truth*, trans.

In the Enlightenment Kant retains this rather tepid qualification but he places great stress on the fact that the duty to avoid gratuitous cruelty to animals is really not a duty to animals at all but rather to humanity.[39] As already noted, for Kant, animals are mere "things," living instrumentalities with no inherent worth of their own.[40] Indeed on Kant's view, animals are ultimately more like vegetables or fertile fields than they are like human beings: "vegetables (e.g., potatoes) and domestic animals…are *made* by human beings…and may therefore be used, expended or consumed (i.e., killed)."[41] One can easily imagine Kant offering a comparable assessment of the moral status of wild animals—that even though they are not "made" by human beings, their moral status is nonetheless that of mere "things" or instrumentalities and hence we have no direct duties whatsoever toward them. In our own time, the political philosopher John Finnis argues that "those who propose that animals have rights have a deficient appreciation of the basic forms of human good," which is to say that the very idea of justice is oriented on the kind of good of which only human beings are capable. Finnis suggests that human good is different than whatever sorts of goods animals may participate in, inasmuch as human but not animal experience is "expressive of decision, choice, reflectiveness, commitment, as fruition of purpose, or of self-discipline or self-abandonment, and as the action of a responsible personality." Justice, in other words, is oriented exclusively on "respect for human good" and has no reference whatsoever to any other sort of good, regardless of anything we might claim about the supposed richness or dignity of animal experience.[42]

This view of justice remains dominant throughout the history of Western thought. Not only does it reduce the idea of injustice toward anyone or anything non-human to absurdity, but its historical emergence coincides with the Stoic proclamation that everything non-human in the natural world exists expressly for the sake of satisfying human needs and desires and the Epicurean assertion that justice is entirely a matter of reciprocal contractual arrangements. The modern formulation of this prejudice is that only human beings possess inherent moral worth, whereas all non-human natural beings possess merely instrumental value. If there is any prospect of overcoming the anthropocentric, speciesistic prejudice of the Western tradition, everything depends on rethinking the self-serving and unjustifiable exclusion of animals from the sphere of justice that lies at its core.

Robert W. Mulligan, et. al., 3 vols. (Indianapolis: Hackett, 1995), 3:138; *Summa Contra Gentiles* 3, Chap. 92, in *Basic Writings of St. Thomas Aquinas*, ed. Anton C. Pegis, 2 vols. (Indianapolis: Hackett, 1997), 2:222.

[39] Kant (1996), sec. 17, p. 193 (emphasis in original).

[40] Kant (2008), sec. 83, p. 298.

[41] Kant, *The Metaphysics of Morals*, Doctrine of Right, sec. 55, p. 115 (Ak. 6:345, translation altered).

[42] Finnis (1980), p. 194f.

7.2.3 Contemporary Defenses of Speciesism

Why is such a rethinking necessary? For unapologetically anthropocentric thinkers such as Richard Posner, there is no need for such a rethinking. Posner suggests that his sense of the absolute moral priority of human beings over non-human animals is based on "a moral intuition deeper than any reason," and he dismisses as "weird" and "insane" any theory according to which animals count anywhere near as much as human beings in the moral scheme of things. To the objection that his view commits the same kind of mistake against rational consistency that the racist or the sexist commits, Posner replies that the analogy between racism and sexism on the one hand and speciesism on the other exhibits "a sad poverty of imagination."[43] But does it? Why should we acknowledge, as Posner does, that racism and sexism are unacceptable on rational grounds, but deny that speciesism is an irrational prejudice? It is here that Posner purports to appeal to "moral intuitions that are deeper than any reason." But are these really *moral* intuitions, or do they instead exhibit the kind of "self-serving inconsistency" that Martha Nussbaum observes to be so pervasive in our judgments about the moral status of animals?[44]

Let us put this question aside for a moment and consider the relative importance that our society places on the predicament of animals—a predicament attested to by the fact that, according to the United Nations Food and Agriculture Organization, over seventy *billion* land animals (over ten times the world's human population) are killed for human consumption worldwide *every year*. The pressing exigencies that confront human beings on a day-to-day basis tend to resolve themselves into three main categories: human health and welfare problems, ecological problems, and problems of animal rights or animal welfare. In the absence of what John Rawls once called "a theory of the natural order and our place in it," these three kinds of problem sit in an uneasy tension with one another, one kind sometimes taking precedence over the others but human health and welfare concerns almost always winning out.[45] Thus, for example, even when people say that we face an imperative of responsibility to exercise stewardship over the natural world, they tend to base this imperative not on anything we owe directly to the natural world but rather on what we owe to future generations of humanity. Only on a view according to which nature and animals are essentially raw materials can we make sense of the devastation that we have visited upon the environment and non-human sentient life. For if we viewed nature or animals as having some kind of inherent worth, we would have to recognize that our actions and our entire way of life constitute an affront to the dignity of the non-human.

So what about Posner's claim that our sense of the categorical superiority of human beings is a moral intuition impervious to reason? This claim is a little too convenient, as is the suggestion, made by many anthropocentric thinkers, that the analogy between the subjection of animals and human slavery is ill-founded. What

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[43] Posner (2004), pp. 65, 58.

[44] Nussbaum (review discussion of Wise 2000) (2001).

[45] Rawls (1999), p. 448.

thinkers like Posner would have us ignore is the fact that a great many non-human animals are conscious, deliberate, feeling, caring, meaning-seeking beings with a tremendous array of cognitive and affective capacities of which we are becoming increasingly aware with every passing day.[46] Posner is not really invoking a ground-floor moral intuition, as he suggests; instead he is relying on an ancient unargued assumption that certain experiential capacities render human beings morally superior to non-human animals. Thinkers who dogmatically proclaim the moral superiority of human beings over animals would have us believe that those rational and linguistic capacities that are unique to human beings just happen to be the capacities that are the most relevant to the consideration of moral status. But what is the significance of the ability to do mathematics or compose symphonies to the determination of a being's moral status? Why not base moral status instead on, say, the ability to care for one's young or the ability to recognize extremely minute differences between faces or facial expressions? More to the point, why attribute inherent moral worth only to those beings who can contemplate things like moral worth in the abstract or who can enter into reciprocally-binding contractual arrangements articulated in human language? And on what grounds do we *attribute* inherent moral worth to human beings who cannot do these things, while *denying* inherent worth to animals with experiential capacities that are more sophisticated than the capacities of some humans?

Germane here is the so-called argument from marginal cases. Whereas thinkers such as Finnis would deny rights to animals on the grounds that animals allegedly lack capacities such as "decision, choice, reflectiveness, commitment," and "self-discipline," and whereas others would deny moral personhood to animals on the grounds that animals cannot use language, use reason, or participate in social contracts, there exist human beings who lack these capacities as well. Yet very few thinkers would be willing to defend the idea that it would be permissible to treat these human beings as animals normally are treated. Many human beings, such as the insane, the senile, infants, the severely mentally retarded, and the comatose, cannot be judged to be rationally autonomous, or to be deliberative moral agents capable of freely entering into relationships of mutual respect. Nevertheless, societies such as ours do not permit the eating of these people or the subjecting of them to painful medical experiments. To claim that animals are not entitled to moral consideration on the grounds that they lack some morally salient capacity, but that senile or comatose human beings do deserve moral consideration in spite the fact that they lack that same capacity, is arbitrary and speciesist. As Daniel Dombrowski notes, absent the identification of a morally relevant difference distinguishing them, it is simply rationally inconsistent to regard "marginal" human beings as possessing moral worth while simultaneously denying that worth to non-human animals. Especially when we

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[46] See, for example, see Correia (2007), Godfrey-Smith (2016), Griffin (1992), Krützen et al. (2005), Mather (2008), Pepperberg et al. (2005), Reiss and Marino (2001), Taylor et al. (2007) and de Waal (2017).

take into consideration human beings who suffer cognitive and psychological impairments, "there does not seem to be a morally relevant characteristic that distinguishes all humans from other animals."[47]

The kinds of "reasons" we offer in an attempt to justify our differential treatment of human beings and animals quickly break down, and it becomes apparent that what we appeal to as reasons are ultimately nothing more than smoke screens for irrational prejudice. We intermingle just enough truth with these prejudices to disburden ourselves of the obligation to interrogate our own deepest motivations. It is true, for example, that only human beings can articulate and endeavor to live in accordance with general principles. Even the primate researcher Frans de Waal, who has done so much to show that a variety of non-human animals exhibit proto-moral behavior, has observed that "we have moral systems and apes do not."[48] But why base moral status on the ability to think systematically, particularly in light of the fact that the record of human history has to make us wonder whether human beings actually live in accordance with systematic principles of justice? De Waal, for his own part, would have us believe that the crux of the matter is not really the ability to think systematically, but rather the fact that giving preference to human beings over animals is an evolutionary imperative. "It is not just that we are biased in favor of the innermost circles (ourselves, our family, our community, our species)," de Waal urges, "we *ought* to be. Loyalty is a moral duty." It is on these grounds that de Waal believes we ought to give moral priority to "an intellectually disabled human" over "any animal."[49] Tom Regan uses somewhat different reasoning to arrive at a very similar conclusion, arguing that it would be justifiable to kill a million dogs (and, by implication, every last non-human animal on earth) to save one human being.[50]

De Waal bases his privileging of human beings on a theory of kinship, whereas Regan bases his on the claim that a human being has greater opportunities for future

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[47] Dombrowski (2006), cf. Dombrowski (1997).

[48] De Waal (2006).

[49] De Waal, *Primates and Philosophers*, p. 165. It is worth noting that de Waal's suggestion that we ought to be biased in favor of our "innermost circles" comes dangerously close to a legitimation of attitudes such as sexism, racism, and nationalism. If indeed one ought to be loyal and extend moral preferences to those with whom one shares a great deal in common, if one ought to prefer one's family, community, species, or any other group with which one is closely affiliated, then there would be little reason for men to refrain from preferring other men, for women to refrain from regarding other women as deserving of greater moral entitlement that men, or for Americans to resist the temptation to discount the moral claims of people from other nations. De Waal may well be correct that the pressures of natural selection have predisposed human beings to prefer those who are judged to be somehow like them. Any such predispositions, however, do not count as moral justification. And to respond by claiming that one ought to prefer one's own species over others, but that one ought not be biased towards one's own sex or race, is just arbitrary.

[50] Regan (1983). On the problematic implications of Regan's resolution of the lifeboat dilemma, see Steiner, *Anthropocentrism and Its Discontents: The Moral Status of Animals in the History of Western Philosophy*, pp. 11–12, 225; for Regan's blithe dismissal of the suggestion that his resolution of the lifeboat dilemma reflects a retreat from the proposition that all animals who count as "subjects-of-a-life" possess inherent moral worth, see his preface to the updated edition of *The Case for Animal Rights* (Berkeley/Los Angeles: University of California Press, 2004), p. xxxiii.

satisfaction than any non-human animal. But do human beings have greater opportunities for future satisfaction? We assert dogmatically and without any actual basis in fact that this is the case. For what, exactly, do most of us know about the experiential capacities of non-human animals? We look, and we see beings that do not communicate with us in terms that are meaningful to us. Does this mean that life is not meaningful for animals? Or does it mean that we humans, who for so long have arrogated to ourselves a godlike place in the scheme of things, lack the capacity to appreciate foreign forms of sentient life? For life is every bit as meaningful to non-human animals as it is to us, even though it is not meaningful in the same ways and even though animals cannot demonstrate this meaningfulness to us in terms that we would accept as dispositive.

And what about de Waal's appeal to the notion of kinship? That, too, ultimately resolves itself into a speciesistic prejudice. For is there any way of justifying the claim that those closer to us have greater moral worth than those relatively distant from us? Certainly it would be understandable if I gave preference to my own child over the child of a stranger in a situation in which I could save only one of them from grave danger. But this can hardly be made into a general moral principle according to which I am entitled in every case to give priority to my own kin, and indeed one of the greatest challenges of morality consists in suspending my desire to give preferential treatment to those closest to me so that I can do justice to those more remote from me.[51] Our relationship to animals is of precisely this nature. But there is this additional consideration: As much as anything else, morality ought to be about extending consideration to those who are most vulnerable to harm or exploitation. And even the most casual reflection makes it absolutely clear that non-human animals are the most vulnerable sentient beings on the planet.

7.2.4 How to Address the Problem of Speciesistic Prejudice

What sorts of moral obligations should we consider ourselves to have toward these vulnerable beings? Of those people who acknowledge that we have moral obligations toward non-human animals, the vast majority are what Gary Francione calls welfarists: they are people who believe that we ought to devote our energies to improving the conditions in which we maintain animals while we confine them, experiment on them, and ultimately kill them. It is in this sense that California's Proposition 2 is a classic example of welfarist thinking. But there are two serious problems with welfarist measures. First, as Francione has amply pointed out, such measures do nothing to stem the exploitation of animals, but instead simply make us feel better about exploiting them—such measures reinforce the sensibility that confinement, experimentation, killing, and the like are perfectly acceptable provided that we perform these practices "nicely." In this connection, Francione observes that

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[51] Derrida goes so far as to suggest that our most profound moral obligations are actually to those most *un*like us. See Derrida (2009).

today there are more animal welfare laws on the books than ever before, and that there is more extensive and more egregious confinement and killing of animals than ever before.[52] The second and more serious problem with the welfarist approach is that it is tragically question-begging: it diverts attention from the fact that the moral baseline is one according to which *we shouldn't be confining and killing animals in the first place*, particularly in light of the fact that few if any human beings on the entire planet actually need to do things like kill and eat animals. We tell ourselves that animals don't know what is happening to them. We tell ourselves that animals kill animals, that we are animals, and that therefore it is perfectly in the order of things for us to kill animals. We tell ourselves a great many things in an attempt to rationalize the things we do to animals. But let us be clear: Ultimately we do these things not out of any genuine need, but simply because the regime of animal exploitation is habitual, convenient, and, in some perverse way, pleasurable. If we really wish to do justice to our linguistic and rational capacities, then it behooves us to articulate and strive to live in accordance with principles of nonviolence, one of whose corollaries is that we ought to grant animals the freedom to live their lives unfettered, just as we seek to live our own.

7.3 Ecosystem Rights

7.3.1 On the Possibility of Ecosystem Rights

Thinkers such as Gary Francione argue that all and only sentient creatures deserve moral consideration and therefore are included in the sphere of justice. On Francione's view, sentient beings have certain interests, such as an interest in not suffering and in continued existence, and rights are moral and legal mechanisms for protecting such interests.[53] A key function of rights is to make explicit and protect the interest that sentient beings have in self-determination, i.e., in determining the course of their own lives without interference from others. Of course, no one, not even a human being, may reasonably expect to engage in acts of self-determination without limit; fundamental to the task of living together with others is the need to accept limits on one's conduct where that conduct unduly interferes with the rights of others to self-determination. This is a proposition that we have little difficulty accepting in the case of relations among human beings; but most in our culture remain highly resistant to the idea that this proposition applies to human-animal relations as well, and particularly to the idea that animals possess rights that we must respect even at the price of our own happiness or convenience.

It is at least in part because of the arbitrary emphasis on certain, putatively uniquely human, forms of rationality through history that animals have been relegated to the

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[52] Francione (1996).

[53] See Francione (2000).

status of instrumentality; the insight that vulnerable creatures with the capacity to suffer and who possess interests in their own well-being do indeed matter morally, should move us to recognize at least sentient animals as full-fledged members of the moral community and pursue the elimination of their exploitation. Francione appeals to the principle of equal consideration of interests to demonstrate that there is a fundamental logical inconsistency in extending rights to human beings while denying them to sentient non-humans, inasmuch as what is decisive for moral status is not any form of putatively sophisticated rationality but simply sentience, the ability to have subjective experiences.[54] Indeed, on Francione's view, sentience is not merely sufficient for moral status but downright *necessary*: on his view, sentient beings can be harmed in ways in which non-sentient beings cannot, and these forms of harm are qualitatively more urgent than the kinds of harms that can be inflicted on non-sentient beings.

Many environmental philosophers, however, go further, and argue that the sphere of moral considerability should be recognized to be even wider. Just as the logocentric prejudice shared by Aristotle and the Stoics (namely, their focus on *logos* as reason or language) has contributed to a cultural bias against recognizing the moral worth of non-human animals, so our having inherited that prejudice has contributed to the exclusion of the rest of non-sentient nature from the moral community. For more broad-minded environmental thinkers, it is not only human beings and non-human animals who are the proper recipients of moral concern, but even non-sentient living beings such as trees and non-living entities such as mountains, rivers, and ecosystems deserve moral consideration.

Aldo Leopold, in his 1949 *A Sand County Almanac*, offers one of the classic and most enduringly influential statements of this position. Leopold argues that through human history, as part of a process of "ecological evolution," the boundaries of the moral community have gradually enlarged to progressively include those previously excluded.[55] In Homeric times, for instance, the "ethical structure" "covered wives, but had not yet been extended to human chattels," such as Odysseus' unfortunate slave girls, "hanged all on one rope" upon his return.[56] Over time, groups of human beings excluded from the moral community have gradually been incorporated into it, and no longer is it thought permissible to regard human beings as property. Leopold claims that the earliest ethical systems governed relations among individuals, and later evolved to govern the relation between the individual and society: "The Golden Rule tries to integrate the individual to society; democracy to integrate social organization to the individual."[57] But Leopold notes that thus far we are lacking an ethic governing humanity's relation to the land. Land, he says, "like Odysseus" slave-girls, is still property. The land-relation is still strictly economic, entailing privileges but not obligations."[58] Given the magnitude of the environmental challenges humanity

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[54] Ibid.

[55] Leopold (1970).

[56] Leopold, *A Sand Country Almanac*, p. 237.

[57] Leopold, *A Sand Country Almanac,* p. 238.

[58] See Footnote 57.

faces, Leopold holds that this further extension of moral considerability is an ecological necessity. As such, he proposes enlarging the moral community to include not just human beings, but “soils, waters, plants, and animals, or collectively: the land [….]. In short, a land ethic changes the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it. It implies respect for his fellow-members, and also respect for the community as such.”[59] We are called to respect members of a community including not just human beings and other animals, but also soils and waters; human beings, as “plain members” of that community, presumably would enjoy no special privileges or rights. Moral considerability extends not just to the individual members of an ecosystem, but even to the biotic community itself. Indeed, Leopold famously claims that conduct ought to be judged not merely in terms of its implications for other human beings or non-human animals, but that we should adopt a much broader perspective when assessing the morality of our choices: “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.”[60] Of paramount moral importance are not individuals, but ecosystems of which they are parts and which sustain them.

The spirit of Leopold’s land ethic animates more systematically developed ecocentric philosophical positions, such as deep ecology. Deep ecologists argue for a holistic vision of human and other creatures as integrated within a natural world in which everything is interconnected. Deep ecologists Bill Devall and George Sessions write:

> Ecological consciousness and deep ecology are in sharp contrast with the dominant worldview of technocratic-industrial societies which regards humans as isolated and fundamentally separate from the rest of Nature, as superior to, and in charge of, the rest of creation […]. For deep ecology, the study of our place in the Earth household includes the study of ourselves as part of the organic whole. Going beyond a narrowly materialist scientific understanding of reality, the spiritual and the material aspects of reality fuse together.[61]

As parts of larger ecological wholes, human beings should recognize that the “earth does not belong to humans,” and that natural phenomena are characterized by an inherent worth independent of their utility to humanity and independent of any recognition of their worth by conscious beings.[62] This position is deeply non-anthropocentric, for the understanding that natural phenomena possess inherent worth entails recognition that those phenomena command moral respect and are in no way subordinate to humanity’s existence and interests. Human beings must learn to stop evaluating all worth merely in relation to their own interests, and must recognize that they possess “no right to reduce” the “richness and diversity” of life “except to satisfy vital needs.”[63] Human rational and spiritual capacities entitle us to no special privilege or moral status. Should human beings’ interests and non-vital needs “come into conflict with the vital needs of non-humans, then humans should

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[59] Leopold, *A Sand Country Almanac,* pp. 239–40.

[60] Leopold, *A Sand Country Almanac*, p. 262.

[61] Devall and Sessions (1985).

[62] Naess (1998).

[63] Naess, “The Deep Ecological Movement: Some Philosophical Perspectives,” p. 439.

defer to the latter,"[64] and therefore we are obligated to re-evaluate prevailing "modes of production and consumption […]."[65] Deep ecologist Arne Naess notes that this orientation towards the inherent worth of all of nature does not refer only to living creatures, but "refers to the biosphere, or more professionally, to the ecosphere as a whole […]. This includes individuals, species, populations, habitat, as well as human and non-human cultures. Given our current knowledge of all-pervasive intimate relationships, this implies a fundamental concern and respect."[66] Indeed, Naess says that deep ecologists employ the term "life" "in a more comprehensive, nontechnical way also to refer to what biologists classify as "non-living": rivers (watersheds), landscapes, ecosystems."[67] In other words, deep ecology adopts "an ecosystem approach rather than the consideration merely of isolated life forms or local situations,"[68] and asks us to recognize that living creatures and even non-living natural entities and systems matter morally and deserve respect.

7.3.2 Animal Rights and Ecosystem Rights

The ecocentric concern with habitats or ecosystems stands in practical and conceptual tension with many of the commitments of animal rights advocates. These tensions are exacerbated when it becomes clear that, at least for many ecocentric thinkers, our duties to ecosystems themselves may well take priority over duties to individuals.[69] Such differing commitments about the relative moral priority of ecosystems and the interests of individual human beings or animals lead to very different views about proper responses to practical challenges. For instance, Leopold's commitment to preserving the integrity and stability of an ecosystem most likely would lead him to endorse the removal (if possible) or culling of invasive species or domesticated animals who had colonized an area only to threaten existing or native flora and fauna.

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[64] Naess, "The Deep Ecological Movement: Some Philosophical Perspectives," p. 442.

[65] Naess, "The Deep Ecological Movement: Some Philosophical Perspectives," p. 441.

[66] See Footnote 63.

[67] See Footnote 63.

[68] See Footnote 65.

[69] The environmental ethicist Paul W. Taylor is critical of the ways in which the holistic positions of thinkers such as Leopold fail to value sufficiently the worth of individual living beings, as they assign worth to the goods of individuals merely instrumentally, insofar as those goods contribute "to the well being of the system as a whole." Taylor (1986). Taylor refers to his own position as biocentric, rather than holistic or organicist, and argues that those entities deserving of respect are individual organisms recognized as teleological centers of life existing in a natural system of reciprocal interdependence; see Taylor, *Respect for Nature: A Theory of Environmental Ethics*, p. 153. However, Taylor's stance must also be distinguished from those of most advocates of animal rights, for although he argues for a non-anthropocentric outlook, his argument for respecting living nature often seems to result in ambiguity about the worth of those creatures he takes to be non-natural or non-wild, such as domesticated animals (cf. Taylor, *Respect for Nature*, pp. 9, 13, 46, 53–8, 167). Because of the nature and scale of the meat industry, the latter typically are of particular concern to animal rights advocates.

Whereas for supporters of animal rights, the culling of invasive animals might be regarded as akin to murder, for an ecocentrist such as Leopold the requirements of ecosystem functioning and robust biodiversity would override the interests of any individual animals impeding that functioning. Indeed, as Mark Sagoff notes, Leopold endorsed hunting as an important means for supporting ecosystem health given the widespread elimination of "top predators."[70] Thus Sagoff says that the "policies environmentalists recommend are informed by the concepts of population biology, not the concepts of animal equality […]. The environmentalist would sacrifice the lives of individual creatures to preserve the authenticity, integrity, and complexity of ecological systems. The [animal] liberationist […] must be willing, in principle, to sacrifice the authenticity, integrity, and complexity of ecosystems to protect the rights, or guard the lives, of animals."[71]

The animal rights and environmentalist approaches share a deep and enduring commitment to the moral dangers of anthropocentrism. Both take as starting points the crucial insight that human beings are not all that matters morally, and that many beings other than human beings deserve to be regarded and treated with respect. The traditional appeals to rationality and the capacity to participate in contractual arrangements as the conditions for moral worth unacceptably restrict the scope of the moral community. For each approach, the boundaries of the moral community ought to be enlarged to include much more than merely *Homo sapiens*. Both approaches also share the view that the anthropocentric constriction of the moral community to include only humanity provides license for people to give free reign to some of their most selfish and dangerous proclivities: by finding reason to relegate all beings other than human beings, including all non-human animals and the entirety of the natural world, to the status of mere resource, the value of which is measured entirely in relation to human needs and desires, human beings take themselves to be permitted to do basically whatever they want with respect to nature and animals (perhaps under the constraint that those practices do not unacceptably harm other human beings in some way). This license has led to tragic and dangerous instances of environmental devastation and to the making routine of horrific practices in the meat and animal experimentation industries. Leopold's urging us to regard ourselves as "plain members" or ordinary citizens of the biotic community, and the animal rights supporters' caution against speciesist bias, both amount to a rejection of the human

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[70] Sagoff (2001).

[71] Sagoff, "Animal Liberation and Environmental Ethics: Bad Marriage, Quick Divorce," p. 90, p. 93. Similarly, J. Baird Callicott writes that most environmentalists are committed to the preservation of ecosystems "at all costs, even if that should mean assassinating the common herbivorous mammals [such as invading domestic cattle and feral goats], while the ethics of animal liberationists and animal rights activists would favor the mammals, even if that should mean further ecological degradation and the erosion of biodiversity." J. Baird Callicott, "Introduction" to Part One of *Environmental Philosophy: From Animal Rights to Radical Ecology*, p. 8. Elsewhere, Callicott quips that since ethical consideration of a biotic community's individual members is "preempted by concern for the integrity, stability, and beauty of the biotic community," Leopold's land ethic threatens to be "holistic with a vengeance." J. Baird Callicott, "The Conceptual Foundations of the Land Ethic," *Environmental Ethics: Divergence and Convergence*, p. 430. Callicott proceeds to offer a defense of the land ethic's capacity to afford due justice to individual human beings.

proclivity to improperly exalt ourselves above the rest of nature and life, such that we mistakenly regard the entirety of non-human creation as existing merely for our own sake and overlook the fact that non-human beings can possess inherent moral worth and deserve respect.

However, the fact that a critique of anthropocentrism lies at the heart of both environmentalist and animal rights approaches to ethics should not mislead us into overestimating the extent to which these approaches are aligned. In fact, reflecting upon the ways in which they diverge is particularly fruitful because it brings into relief some fundamental ethical questions. The main points of conceptual contention between the animal rights approach and the environmentalist approach turn on questions about whether individuals or systems are the primary recipients of respect, and whether sentience or consciousness is a necessary or sufficient condition for counting morally. The answers to both of these questions depend upon the answer to a yet more fundamental question: what are the conditions for moral worth? As Kenneth E. Goodpaster puts the point, "We need to understand better [...] the scope of moral respect, the sorts of entities that can and should receive moral attention, and the nature of the "good" which morality [...] is supposed to promote."[72] Where do the boundaries of the moral community really lie? Who or what qualifies as deserving of moral respect, and on what grounds?

As noted earlier, according to many thinkers arguing for animal rights, what qualifies one as deserving of moral consideration is sentience. Sentience is connected with the capacity to be aware of a situation and to be sensitive to its mattering; because we can feel pleasure and pain, we have something at stake in a situation, there are phenomena we avoid or pursue. Sentience makes it possible to have interests. Human beings may have more interests, or more complex interests, than most other animals. But all sentient creatures have at least certain basic interests, namely, an interest in not suffering, an interest in continued existence, and an interest in self-determination; and these interests require moral recognition. On this view, not all beings have interests, for not all beings have needs that matter to them. Rocks and cars do not have anything matter to them. Cars need certain things to do what cars do, but whether these needs are met does not matter to them because they have no awareness; it would make little sense to assert that they possess interests. But sentience makes it possible for needs to become interests. Accordingly, Bernard Rollin writes:

> Very simply, "interest" indicates that the need in question *matters* to the animal... [W]hat makes these needs interests is our ability to impute some conscious or mental life, however rudimentary, to the animal, wherein, to put it crudely, it seems to care when certain needs are not fulfilled. Few of us can consciously articulate all of our needs, but we can certainly know when these needs are thwarted and met. Pain and pleasure are, of course, the obvious ways these facts come to consciousness, but they are not the only ones. Frustration, anxiety, malaise, listlessness, boredom, anger are among the multitude of indicators of unmet needs, needs that become interests in virtue of these states of consciousness. Thus, to say that a living being has interests is to suggest that it has some sort of conscious awareness, however rudimentary...The presence of pain in an animal obviously would be a sufficient condition

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[72] Kenneth E Goodpaster, "On Being Morally Considerable," *Environmental Philosophy: From Animal Rights to Radical Ecology*, p. 57.

> for saying it has interests, though a creature could have interests without having the ability to feel pain, as long as it had some needs that mattered to it. (Pain is, of course, only biologically useful if a creature can be aware of it and bothered by it.)[73]

Claiming that it is not only sentient beings who have needs and interests, however, Goodpaster wonders at the reluctance to "acknowledge in non-sentient living beings the presence of independent needs, capacities for benefit and harm, etc.,"[74] and says that, "Neither rationality nor the capacity to experience pleasure and pain seem to me necessary (even though they may be sufficient) conditions on moral considerability [...]. Nothing short of the condition of *being alive* seems to me to be a plausible and nonarbitrary criterion."[75] For Goodpaster, living creatures as self-sustaining organized beings have needs that must be met in order to maintain their functioning, and, when they attribute the only morally relevant interests to sentient animals, animal rights advocates do not go nearly far enough. And perhaps the idea that non-sentient beings should have interests is not as surprising as one might at first think. In order to lend credibility to the idea that sentience is not a precondition for the possession of interests, Goodpaster quotes Christopher Stone:

> I am sure I can judge with more certainty and meaningfulness whether and when my lawn wants (needs) water than the Attorney General can judge whether and when the United States wants (needs) to take an appeal from an adverse judgment by a lower court. The lawn tells me that it wants water by a certain dryness of the blades and soil – immediately obvious to the touch – the appearance of bald spots, yellowing, and a lack of springiness after being walked on; how does "the United States" communicate to the Attorney General?[76]

We routinely attribute needs and interests to a range of non-sentient entities, from nations to markets to universities to companies to estates. If doing so is meaningful, then why not attribute interests to trees or ecosystems, whose functioning also is capable of being hindered or furthered? If such entities have interests, then on what grounds would we not think it important to take those interests into account in our moral deliberations? If at least some of the important interests of human beings are protected by means of the mechanism of moral and legal rights, and if the interests of non-human entities such as corporations are protected by means of the same mechanism, then why not afford such rights to non-human entities such as animals,

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[73] Rollin (1992).

[74] Goodpaster, "On Being Morally Considerable," p. 66. He suggests that thinking that sentience is the necessary condition for moral considerability is connected with overly narrow hedonistic views of value: "if one's conception of the good is *hedonistic* in character, one's conception of a beneficiary will quite naturally be restricted to beings who are capable of pleasure and pain. If pleasure or satisfaction is the ultimate gift we have to give, morally, then it is to be expected that only those equipped to receive such a gift will enter into our moral deliberation." Goodpaster, "On Being Morally Considerable," p.66.

[75] Goodpaster, "On Being Morally Considerable," p.58. It must be noted that although all life deserves moral consideration, Goodpaster does not consider sentient life to be equal in moral significance to non-sentient life. All life has moral worth, for him, but sentient life may well count for more.

[76] Stone (1974), cited in Goodpaster, "On Being Morally Considerable," p.68.

trees, species, and ecosystems?[77] Similarly, Callicott laments the “psychocentric” and individualistic bent of standard moral theory, of which animal rights theory would be a species, for that orientation precludes moral “consideration of wholes—of threatened *populations* of animals and plants, or of endemic, rare, or endangered *species*, or of biotic *communities*, or, most expansively, of the *biosphere* in its totality – since wholes per se have no psychological experience of any kind.”[78] For Callicott, the narrow focus on sentient individuals obscures the importance of a whole range of natural entities that deserve to be recognized as possessing moral worth.

7.4 Toward a Non-anthropocentric Relation to Nature

The prospect of taking seriously the notion of animal or ecosystem rights depends crucially on a critical rethinking of the ancient prejudice that human beings are the crown of creation. This prejudice has its roots in ancient Greek and Judeo-Christian thought and is evident in the shift from stewardship to dominion sketched in the first nine books of Genesis: Nature is initially a garden in which humans live peacefully with other beings and are assigned a vegetarian diet; it is only after the flood that our relationship to nature becomes transformed into one of dominion, a relationship in which animals will have "fear and dread" of us and God smiles approvingly on our use of animals as instrumentalities.[79] We have seen that medieval Christian thinkers such as Augustine and Aquinas seize upon this notion of dominion and make it a central pillar of their views about the proper place of human beings in the world. Even if by the time of the Enlightenment our culture no longer conceptualized the human prerogative to dominate nature as a divine bequest, Kant having reduced God to a postulate of pure practical reason, it remains the case that thinkers such as Kant nonetheless conceive of the human being as "the titular lord of nature" and maintain that “without human beings the whole of creation would be a mere desert, existing in vain and without a final end.”[80]

Our culture’s shift away from a theocentric conception of existence has led to a singularly anthropocentric one. But the same considerations that led to an abandonment of theocentric thinking might well lead us to an abandonment of anthropocentrism, or at least to a critical reevaluation of it. Such a reevaluation would require

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[77] One question to be addressed in this connection is whether the analogy between corporations and non-sentient natural beings is ultimately a fruitful one: The legal doctrine of “piercing the corporate veil” was devised to dispel the notion that corporations are themselves persons, a notion that effectively shielded the actual persons operating corporations from liability. Is there a comparable “veil” to be pierced in the case of trees or ecosystems?

[78] Callicott, “The Conceptual Foundations of the Land Ethic,” p. 430.

[79] See Steiner, *Anthropocentrism and Its Discontents: The Moral Status of Animals in the History of Western Philosophy*, pp. 112–3; particularly revealing in this connection is a comparison of Genesis 1 and 2 with Genesis 8 and 9.

[80] Kant, *Critique of the Power of Judgment*, sec. 83, p. 298; sec. 86, pp. 308–9.

us to rethink the anthropocentric orientation of traditional ideals such as cosmopolitanism, the ideal shared by the likes of Diogenes of Sinope and Kant that we do best by aspiring to be "citizens of the world."[81] How we give shape to this ideal depends crucially on something that Rawls rightly observed to be at the core of any robust conception of morality—"a theory of the natural order and our place in it." We have come far enough to call into question the ancient prejudice that God or the gods created nature for the sake of human beings, but we have not yet made the logical next step: to see nature as a totality of which we are but a mere part. The Christian thinkers placed a great premium on the virtues of *caritas* (love or charity) and humility in the face of a cosmic community larger than ourselves; but it would have been anathema to them to suppose that humility involves a recognition that we are in fact not superior to the rest of nature, and they would never have accepted the proposition that we might have obligations to practice charity in relation to anyone or anything other than a fellow human being.

Kant, for all his purported "enlightenment," hardly made a step beyond this thinking in his own views on the natural order and our place in it. A corollary of his person-thing distinction is his focus on charity as an obligation owed to our fellow *human* cosmopolitans.[82] Thus Kant was unable to think past the anthropocentric prejudices of the tradition, even though he had made a decisive move to "religion within the limits of reason alone." More recently, thinkers such as Karl Löwith have sought to challenge this lingering anthropocentrism by situating human political (and, by implication, moral) relations within a larger cosmic context. Löwith maintains that "human community cannot be in order when it is not in tune with the cosmos [*kosmosartig verfaßt*]." We must acknowledge that the world is not merely the human world and that there iss "a pre- and suprahuman world of sky and earth, which stands and maintains itself utterly on its own [and] infinitely eclipses the world that stands and falls with human beings…[It] does not belong to us, but rather we belong to it."[83] This call to see ourselves as inscribed within a larger cosmic whole of which we are a mere part is an extension of Löwith's teacher Heidegger's ideal of a mode of human dwelling that "lets beings be" and "ponders the abode of human beings" rather than seeking to do violence to nature by imposing anthropocentric demands on it.[84]

Whether we are prepared to take the decisive step into this kind of humility in the face of what is *not* human remains an open question. What is indisputable is the fact that the possibility of doing true justice to non-human beings, be they sentient or non-sentient, depends crucially on our willingness to do so.

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[81] See Laertius (2000) and Kant (2001).

[82] Immanuel Kant, "The Contest of Faculties," *Political Writings*, p. 188; *The Metaphysics of Morals*, pp. 192, 215. For an argument that Kant's work nevertheless offers resources helpful for reflection upon moral obligations towards nature, see Lucht (2007).

[83] Löwith (1981).

[84] Heidegger (1998); "Letter on 'Humanism'," *Pathmarks*, p. 271.

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Chapter 8
A Phylogenetic Approach to Conservation: Biodiversity and Ecosystem Functioning for a Changing Globe

Michael F. Allen and Brent D. Mishler

Abstract As late as the sixteenth century, the world was a matrix of primarily wildlands. But due to technology development and population growth, humans increasingly altered natural habitats and modified other organisms to suit our needs. The world became "all about people"—the rest of the natural world became enslaved to us. By the eighteenth and nineteenth centuries, calls emerged for conservation and the new field of ecology developed, resulting in legislation to form national parks and save endangered species (e.g., the Endangered Species Act in the US). This "one species at a time" approach can be credited with saving a number of individual taxa, but is insufficient to deal with the modern global biodiversity crisis given the urgent pressures on remaining natural lands. We argue that considerable expansion is needed in conservation biology, moving from the single species approach to an area based approach incorporating all species and a broad phylogenetic definition of biodiversity. Biodiversity should not be considered as just the arbitrary level at which species are named—instead it is the whole tree of life. We discuss newly developed approaches to multiple species habitat conservation plans and new spatial phylogenetic methods that take into account all levels in the tree of life when making conservation decisions. To protect biodiversity, we must use all the tools we have to identify and protect landscapes that allow for future dynamics, while considering the conditions of the past and present.

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8.1 Introduction

Life on our planet has undergone dramatic swings throughout the past 4 billion years. New lineages have emerged and diversified, yet many large groups have also gone extinct. Some lineages are driven to near extinction due to environmental perturbation, only to re-emerge as dominant taxa. According to one hypothesis, our own lineage may be an example due to the Toba eruption bottleneck, about 75 millennia ago (Rampino and Self 1992). Luckily for us, our species was widespread enough that a population in South Africa persisted, and then re-spread around the globe. *Homo sapiens* probably reached our global carrying capacity some 8 millennia ago (e.g., Christian 2011). But, due to our capacity for technology development, our population continued to expand. This technological development allowed us not only to expand into new habitats, but also to alter them to suit our needs. We got into the habit of treating all other species of organisms as our servants, through habitat modification (e.g., burning) to facilitate organisms we prefer, and then by directly modifying their genetics through domestication and controlled breeding. The world increasingly became "all about people" and the rest of the natural world became enslaved by humans.

The agricultural revolution turned wildlands surrounding individual villages into altered production lands that in turn, enabled more human production requiring more land development; approaching an infinite do-loop of human growth and land utilization. As late as the sixteenth century, most of the world was a matrix of wildland forests, grasslands, and shrub lands with interspersed patches of villages and farmlands (e.g., Strauss 1976). But by the twentieth century, the vast majority of the globe was human-managed land interspersed with patches of wilderness. Nineteenth century paintings such as Thomas Cole's *Catskill Creek* show ravages of industrial depletion of the forest, and the paintings of Grandma Moses, such as *Hoosick Valley*, showing forests remaining only on the hilltops, riparian ribbons, and along stone fences. The extensive forest across the lowlands, supporting large populations of deer, moose, bear, wolves, and other large mammals have been replaced by crops and cattle. Even today, the largest white pines, *Pinus strobus*, are found along hillsides, where they established along stone fences and stone protections (see Thoreau *Succession*), instead of the ancient valley-bottom stands such as the Pisgah Forest in southern New Hampshire, destroyed in the 1938 hurricane.

By the eighteenth and nineteenth centuries, calls emerged for protecting the wild beyond just the king's hunting preserves. For example, among the most articulate, Henry David Thoreau said (*Maine Woods* 1864):

> Why should not we, who have renounced the king's authority, have our national preserves, where no villages need be destroyed, in which the bear and panther, and some even of the hunter race, may still exist, and not be "civilized off the face of the earth,"—our forests, not to hold the king's game merely, but to hold and preserve the king himself also, the lord of creation,—not for idle sport or food, but for inspiration and our own true re-creation?

While protections of hunting preserves, such as the Białowieża Forest in Poland, have been ongoing since the Middle Ages, protections of unique landscapes and endangered animals such as the American Bison (*Bison bison*) began in March of 1872, when President Ulysses S. Grant signed the Yellowstone National Park Protection Act (1872) into law to protect "from injury or spoliation, of all timber, mineral deposits, natural curiosities, or wonders within said park, and their retention in their natural condition" (Sect. 2). Subsequent national and international parks through the twentieth century have been designed to protect animals as well as geological curiosities into the foreseeable future. A slowly growing number of people began to realize that nature, and the other species on the tree of life, might have their own intrinsic value distinct from human needs.

The next major fundamental step was the establishment of the field of ecology, ökologie, in 1866 by Ernst Haeckel—a fundamental integration of evolution by natural selection as outlined by Charles Darwin and Alfred Russell Wallace, with natural history, biology, and geology. This field recognized that all organisms, from microbes to vertebrates, form an integral and interactive complex of pieces that comprise the community.

8.2 Twentieth Century Approach and Recognition of Biodiversity

In the early twentieth century, Frederic Clements (1916) proposed the idea of a "climax" ecological community. Specifically, following disturbance 4 or 5 stages lead toward a climax community that was the natural, or primeval state based on soils and climate. Simultaneously, the recognition that many species important to our national identity, the Bald Eagle, the Grizzly Bear (on the flag of the State of California), and the American Bison, were undergoing extirpation, or even extinction. The Endangered Species Act (ESA), passed nearly unanimously in 1973, was intended to protect these symbols. The Bald Eagle, *Haliaeetus leucocephalus*, recovered largely due to the banning of DDT in the US and Canada, along with protections from illegal shooting and habitat protection.

Interestingly, management efforts and funding were applied in attempting to sustain or recover populations of endangered species. Wetlands, such as the Aransas National Wildlife Refuge on the Texas Coast and the Wood Buffalo National Park in the Northwest Territories of Canada, were managed for protecting wintering and breeding habitat for Whooping Cranes, *Grus americana*, along with refuges along the migratory route, like the Cheyenne Bottoms and Quivira National Wildlife Refuges. These lands were protected and managed, at considerable costs both for recreation and for the threatened taxa.

But the globe was rapidly changing. Since 1950, the global human population has increased from 2.5 to 7.8 billion and the USA from 152 to 331 million. Much of the remaining wildland matrix was reduced to small islands within the larger human landscapes. Since 1973, the ESA was applied to species such as the Snail Darter (*Percina tanasi*) and the Stephens' kangaroo rats (*Dipodomys stephensi*), taxa that were not considered national icons. However, the broader recognition that protecting these few species provides umbrella protection to a much broader host of species living in the same ecosystems, meant that by late in the twentieth century, the ESA, coupled with numerous state laws, became the major land-use planning law nationally for protecting biodiversity, and formed the basis of many international laws and regulations. Thus, the ESA became the primary unplanned authority for constraining widespread land development (Scott et al. 2006).

Notably, there have been successes with the ESA approach to protecting taxa. The ESA has been credited with recovering 39 species, along with preventing extinction in 291 additional species (https://www.biologicaldiversity.org/campaigns/esa_wild_success/). However, protections for individual taxa are continually subject to political pressures. For example, the California gnatcatcher, *Polioptila californica* ssp. *californica*, is continually subject to criticism as to whether to include it as it is also found in Mexico, and whether it is distinct "enough" for protection. In some cases, patches of less than a HA are "protected" by fencing, such as the Otay tarplant, *Hemizonia conjugens* (Sullivan and Scott 2000).

While this "one species at a time" approach can be credited with saving a number of individual taxa, is it sufficient in view of the current global biodiversity crisis—is it the only future of conservation? The need is urgent with many pressures on the remaining natural lands. The ESA-type approach of listing large, charismatic "umbrella species" is slow because of the legal process involved, and in any case may not be the best way to prioritize conservation of remnant wildlands to sustain the maximum of total biodiversity. To proceed with highest efficiency in this crisis we need to clarify we mean by "biodiversity" and consider carefully the best methods for focusing our conservation actions.

8.3 Emerging Issues at the Turn of the Twenty-First Century

Allen, Mishler, and Moritz (American Institute of Biological Sciences 2004) produced a report for the Infrastructure for Biology at Regional to Continental Scales (IBRCS) Program. Here we defined *Biodiversity* as "*the entire tree of life from the smallest gene lineage through its many nested branches of organisms and all their ecological interactions.*" Note that we did not single out species as a fundamental unit. As Solbrig et al. (1991) noted, "The diversity found within species is the ultimate source of biodiversity at higher levels." The Rio de Janeiro Convention on Biological Diversity noted ""Biological diversity" means the variability among living organisms from all sources… within species, between species and of ecosystems" and the NRC report states that "Biodiversity (or biological diversity)" refers to the number of species and extent of genetic variability in those species in a given site.

As the matrix shifts from wildland to anthropogenic ecosystems, individual populations will be lost as these populations become constrained and isolated, and wink out of smaller or more perturbed habitats. Many genetically-distinct populations, linked under the umbrella of a shared species name, are actually quite different. Many of these populations with unique traits play key roles in ecosystem function, and when a patch is lost to development or change, unique populations are lost because of the species concept accepted for that group.

Therefore, as pointed out by Mishler (2010) and Mishler and Wilkins (2018), biodiversity should not be considered as just the arbitrary level at which species are named—instead it is the whole tree of life. Species are not comparable between lineages. They comprise an arbitrary cut-off somewhere along a branch in the tree of life (Mishler 2021). There are clades smaller and larger than the traditional species level and they are all of potential importance to the functioning of ecosystems and worthy of conservation consideration.

In the remainder of this chapter, we first discuss an important shift in viewpoint to a multiple species conservation approach and contrast it with the limitations of focusing conservation on one species at a time. Finally, we advocate taking a phylogenetic approach that takes into account all levels in the tree of life when making conservation decisions. We argue that considerable expansion is needed in conservation biology, from a single species approach to an area-based approach incorporating all species and a broad phylogenetic definition of biodiversity.

8.4 The Reasons to Shift to a Multiple Species Approach

While we do not advocate abandoning the ESA, we strongly believe that other and often better tools are needed for prioritizing areas for conservation, because of several constraints that are present when depending on listing and protecting individual species. Modern approaches that take into account the full suite of species is an important step forward. Many concerns with single-species approaches were identified in putting together one of the largest of the habitat conservation plans (HCP), the Western Riverside County Multiple Species Habitat Conservation Plan (WRC-MSHCP), in southern California beginning in the late 1990s.

8.4.1 Lack of Distributional Knowledge

Many named species are only rarely found, but are they truly rare and in need of protection, or simply have not been looked for adequately? Distributional data requires extensive surveys independently through multiple simultaneous efforts. These data are crucial for a realistic estimate of the impact of *take* on a taxon (Kareiva et al. 1999). But obtaining adequate data (as per Kareiva et al. 1999; Rahn et al. 2006), is constrained both legally and temporally. Trespassing on private land in many countries, even for survey of potential species of concern, is illegal. Obtaining existing data records is challenging. For example, for species of interest in the WRC-MSHCP, Thomas Scott and a legion of students photocopied every survey throughout city and county offices to identify records of observations. Allen and postdocs queried museums for records locally to internationally. John Rotenberry and his lab created niche models where adequate data existed, to identify potential critical lands and to facilitate follow-up surveys where possible. Despite this effort, involving tens of conservation biologists, there were never enough data.

Some organisms are likely undergoing extinction but never reach a protected level of concern. Microorganisms are especially sensitive to this caveat, yet they carry on virtually every ecosystem process on Earth. Small organisms, including fungi, many of whom have macro-organismal fruiting structures (mushrooms), are challenging for protection in this regard (Raphael and Molina 2007). A few taxa, such as *Boletus rhodopurpureus*, a species existing only in older oak and beech stands in Eastern Europe, are well enough described to have obtained protection. In another case, *Rhizopogon brunsii*, a recently described southern California species, shows a limited range (Grubisha et al. 2005) and appears to be sensitive to nitrogen deposition and fertilization (Sirajuddin 2009). Another species, *Rhizopogon mengei* (Allen et al. 1999) was found in two locations, central California and southern California, with an unexpected host (*Adenostoma fasciculatum*), being usually found in association with conifers. It also has apparently only been found in the mid-1990s, during a series of wet years (warming ENSO signal). Species of *Rhizopogon* are important food sources for many small mammals and are critical in the recovery of ecosystems from fire (Glassman et al. 2016). In these cases, all of these collections have been found in protected locations, either research natural areas or as protected watersheds. How many such species have we completely missed elsewhere?

8.4.2 Political Constraints

There are numerous political constraints to listings. In part, this comes from current land management activities, and in part from projected needs. Because of political sensitivity, both the numbers of listings and the time scale for determinations have become far too long for efficient protection, with status reviews taking years to decades. As an example, we note the cases of the California Spotted Owl, *Strix occidentalis occidentalis* and one of its prey, the San Bernardino Flying Squirrel, *Glaucomys sabrinus californicus*. Both were listed as taxa of concern in the WRC-MSHCP in 2004. The range of both species includes the southern Sierras, the Transverse Ranges, and Mount San Jacinto down the Cuyumaca Mountains. In 2010, the Center for Biological Diversity proposed listing the San Bernardino Flying Squirrel (https://www.biologicaldiversity.org/species/mammals/San_Bernardino_flying_squirrel/endangered_species_act_profile.html). In 2012, the FWS reported a positive finding. But, in 2016 FWS reported that this species does not require protection under the ESA. The California Spotted Owl was proposed for listing in 2000. In 2012, this review resulted in a ruling that protection might be warranted. A review was initiated in 2015. In 2019, the FWS finding was that protection was not warranted. Their persistence is dependent on existing habitat supporting these taxa. The persistence of these taxa in some areas may be susceptible to factors that were not considered over the long review period. We will return to this system later.

8.4.3 Dynamic Distributions

Distributions are dynamic. But critical habitat locations are determined based on surveys, often at one or a few points in time. Critically, the "no surprises" rule provides that no new funds or land be required once approval is granted. This rule constrains new data, and even concepts. The impacts of climate change, disease, and air pollution were rarely documented for species of concern by the late twentieth century. Thus, conservation plans are largely static. In a few cases, changes can be documented in spatial dispersion through time, and as weather and vegetation change. For example, between 2004, when the western Riverside County Multiple Species Habitat Conservation (WRC-MSHCP) was signed, and 2012, following severe drought, the suitable habitat of California gnatcatcher *Polioptila californica*, shifted upward in elevation, oftentimes moving from protected lands into unprotected landscapes (Van Tassel et al. 2017). Across the longer time frames of many plans (75 years for the WRC-MSHCP), climate change is emerging as a major challenge. The spatial distribution of the Quino checkerspot butterfly (*Euphydryas editha quino*) has spatially shifted from an almost exclusively coastal range, up into foothills and mountains, buffered from drought (Preston et al. 2012), and models incorporating climate change into distribution patterns suggest this taxon may need a different design than is currently reflected in the WRC-MSHCP (Preston et al. 2008).

Many species exhibit metapopulation dynamics. Only some of the habitat patches across a landscape or region are occupied at any one survey period. An example is the Desert Bighorn Sheep, *Ovis canadensis nelsoni.* The desert bighorn sheep occupy isolated mountain ranges that result from the expansion of the Great Basin and faulting resulting in a Basin and Range desert mountain pattern. This species moves from mountain range to mountain range occupying first this range, then that, depending upon the numbers and the nearly random patterns of individual rainstorms. Thus, the occupation of long-term suitable habitat patches is not predictable but across time, all are occupied at some point. Desert lowlands distributed between mountain ranges, is not habitat, but the sheep do cross while traveling between ranges for sex or chasing past rains (Bleich et al. 1990). What this means is that the desert bighorns require maintenance of unoccupied habitat and corridors across which to migrate to persist.

8.4.4 Corridors: Environmental Change, Variability, and Disease

Corridors, or pathways of suitable habitat, become crucial to sustaining viable populations of many species. Yet most "critical habitat" lands depend on occupancy observations or models for determination. The corridors for the desert bighorn can sometimes be identified, but often animals that are migrating between suitable mountain ranges are found far from predicted locations. Building in suitable unoccupied and corridor habitats is scientifically difficult and politically challenging, even using current climate condition models. As temperatures increase with climate change and precipitation patterns shift determination of critical habitat becomes even more challenging (e.g., Allen et al. 2014). Again, in the case of the desert bighorn, an epizootic pneumonia, likely introduced by contact with domestic sheep may be responsible for much of the population losses. The contacts occur not necessarily in protected core mountain habitats, but during movement through unprotected areas.

In some cases, perturbations remote from “critical habitat” may be crucial. Protecting the habitat directly occupied is likely inadequate for protection of the species. The sand inputs to maintain the large dunes necessary for persistence of the Coachella Valley fringe-toed lizard, *Uma inornata*, comes from the nearby little San Bernardino mountains, from large rainstorms washing sand onto the valley floor, followed by aeolian movement to the current habitat. Human urban and exurban developments between the protected point of the Joshua Tree National Park (JTNP) and the protected dunes occupied by this lizard determine the size and persistence of the dunes critical to population persistence (Barrows and Allen 2007).

In other cases, far-away land use sets up challenging conflicts. Large-scale solar developments are designed to reduce greenhouse CO_2 production and its offshoot-global warming. But these developments also require water for energy production and site maintenance (Allen and McHughen 2010), potentially far more than is sustainable for maintaining groundwater. Yet locations downstream of proposed solar developments (for groundwater flow) where groundwater emerges, at least part of the year, is critical for plants, including endangered taxa (e.g., the Amargosa niterwort, *Nitrophila mohavensis* and ash meadows gum plant, *Grindelia fraxino-pratensis*). Groundwater emerging in springs is critical as waypoints for the desert bighorn, and is affected both by solar development and by climate change. While the transition to renewable energy is probably critical for groundwater over the long term, over the short-term, water use could be devastating for individual endangered and threatened species (Hernandez et al. 2015, 2019).

In other cases, climate change, whether long-term or shorter perturbations such as decadal-scale drought, alter organisms upon which a species of concern depends. For an example, we can return to the California Spotted Owl. In southern California, this taxon depends upon the San Bernardino flying squirrel. A large portion of the squirrel’s diet is comprised of truffle fungi. One of us has studied these fungi for three decades in this region (e.g., Allen et al. 2005). Molecular surveys show the truffle taxa such as *Melanogaster*, *Hymenogaster*, and *Tuber*, on the roots of oaks from the oak woodlands up to the subalpine regions. But sporocarps, upon which the flying squirrels feed, are formed only during years of high precipitation or in wetter habitats such as high elevation regions of the San Bernardino Mountains and Orange County. The connecting populations of the spotted owl through the San Jacinto Mountains were found at 14 survey points (Biological Monitoring Program 2014, <https://www.wrc-rca.org/about-rca/monitoring/> , iNaturalist, <http://flyingsquirrels.sdnhm.org/>), at the higher elevation locations of the San Jacinto Mountains. However, they were not found in the Santa Ana Mountains or the southern San Bernardino Mountains bioregion. What happens, as extreme drought conditions increase and forest fires increase, remains unknown. Without corridors for species to move, and as protected habitat declines in quality and area, populations of taxa of concern will necessarily decline. Do these populations become examples of sky islands, where taxa slowly wink out with global warming? If so, how can the ESA protect critical habitat?

In summary, critical habitat for the protection of species of concern entails far more than identification of lands upon which a taxon is found at the time of determination, and takes far too much time and expense for current endangered species regulations. Furthermore, only rarely do we really know a species well enough to know where all it fits within the broader ecosystem and food chain structure, necessary for the persistence of that taxon and all others dependent upon it or upon whom it depends. The interconnections are simply too numerous and biodiversity too interdependent to focus only on specific taxa. We need instead in this crisis to shift our focus to a landscape perspective, looking at all biodiversity at once in an evolutionary context, using quantitative and spatially-explicit methods.

8.5 Advantages of a Multiple Species Planning Process

The end of the twentieth century and the dawn of the twenty-first century brings the opportunity to rethink the needs and mechanisms for approaching conservation. In the face of the current mass extinction wave, climate change, and bureaucratic lethargy, a single taxon approach, even when coupled into HCPs, will not overcome the biodiversity crisis. There were multiple calls for individual species protections in Riverside County. Even had those locations been set aside, a large number of taxa would have been extirpated between the initial planning and today. Moreover, a wide range of individual taxa in phyla from birds and mammals to fungi to microbes, would have already disappeared. As of this writing, the WRC-MSHCP has acquired approximately 82% of its land protection goal (https://www.wrc-rca.org/about-rca/newsletter/).

Importantly, both our principles of taxonomy and of land preservation precede the concept of evolution. The concept of NCCPs and MSHCPs arose at the same time when the Long-Term Ecological Research began to think beyond single site experiments (the Cross-Site competition) and began to construct the continent-wide scale National Ecological Observatory Network (NEON). As part of our discussion, a need to protect not only individual species, but clades with a limited number of taxa where evolutionary processes can ensue, was formulated (AIBS 2004). Once there were many taxa within the Hominidae. If *H. sapiens* goes extinct, there are no other taxa that can emerge with a similar niche. Alternatively, if the polar bear, *Ursus maritimus,* disappears from northern Alaska, a hybrid between it and *Ursus arctos horribilis*, could well survive and reoccupy that niche in the next ice age. We need to re-think not just protecting current space occupied by threatened species, but the range wherein biodiversity is sustainable ecologically and evolutionarily.

In many regions of the US and globally, federally- and state-listed species are widely distributed (Fig. 8.1). If we plot the distributions of all of the species of concern, almost every potential development, from housing to roads would contain a likely distribution point (Fig. 8.2). The RAND corporation (Dixon et al. 2008) estimated that for the 173,371 acres that are not under protection by other agencies (450,000 acres), the cost to protect them would be $5055 million. Allen estimated in 2003 that purchasing the parcels with known occupancy for Federally or State-listed species would be $5699 M. Moreover, based on modeled distributions that would include lands not yet surveyed, the cost for the eight federally-listed species alone would exceed $16,000 M. Thus, an MSHCP is fiscally prudent.

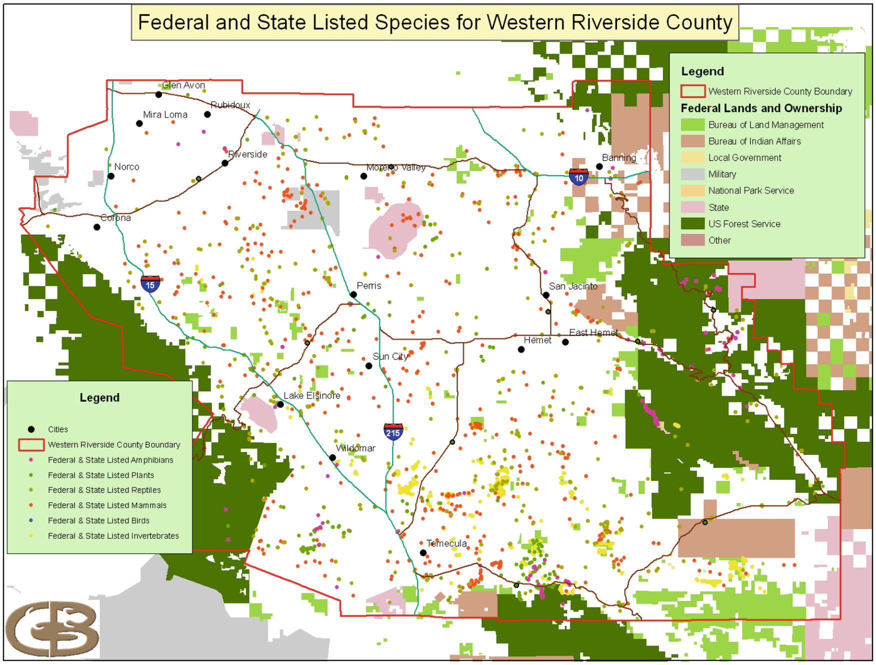

Fig. 8.1 Known spatial distribution of federally and state listed endangered species within the Western Riverside County multiple species habitat conservation plan area. Data mapped from known points compiled by the University of California-Riverside Center for Conservation Biology

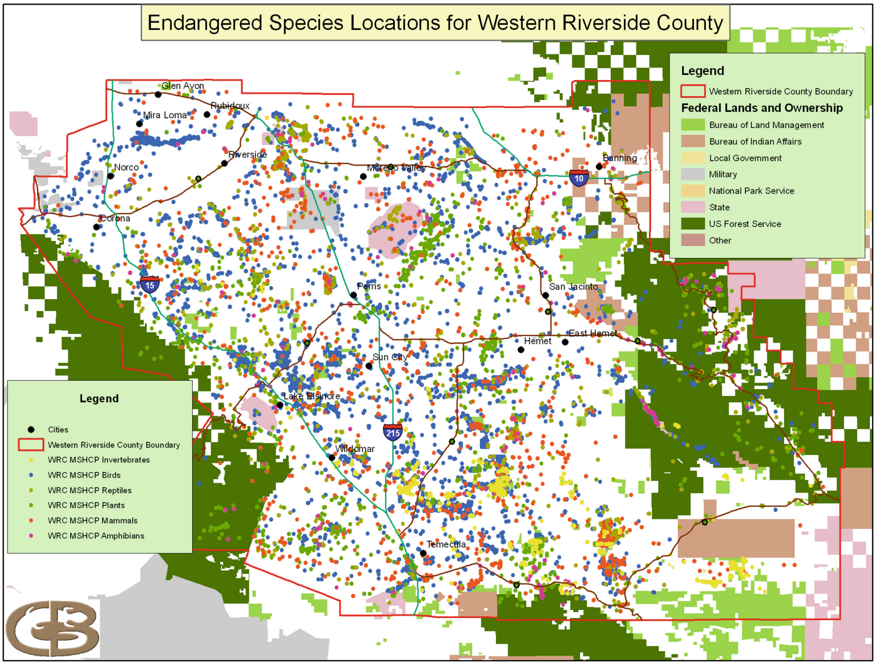

Fig. 8.2 Known spatial distribution of species of concern identified during the planning process within the Western Riverside County multiple species habitat conservation plan area. Data mapped from known points compiled by the University of California-Riverside Center for Conservation Biology

8.5.1 Protecting Biodiversity Broadly Provides Multiple Ecosystem Services

Air and water quality benefit from the forests and native wildland and watersheds protected by habitat conservation plans such as the WRC MSHCP. Atmospheric CO_2 is also reduced by maintaining lands for biodiversity instead of development. For example, native vegetation protected under the WRC MSHCP sequesters between 59,000 and 175,000 (depending upon precipitation) tons of carbon annually. Using a $15/ton, market estimate, that means between $886,000 and $2.6 M worth of carbon (C) credits are provided. This compares with an estimated loss of 22,000 tons C per year directly, or up to 5,000,000 tons C per year indirect (water pumping, refineries, power plants, non-point source transportation) inputs to the atmosphere worth $75 M in carbon credits (Allen 2020). Habitat conservation plants are worth their costs.

8.5.2 Ecologically Effective Planning Incorporates Climate Change and Migration

The broader WRC-MSHCP coupled the federal MSHCP plan to the State of California NCCP (Natural Communities Conservation Protection) principles (Allen et al. 2003). Within this context, no taxon exists independently of its community. Indeed, one of the key approaches to understanding community ecology is embedded into impacts of the surrounding community on an individual organism (MacMahon et al. 1981, where a community is comprised of "The organisms which affect, directly or indirectly, the expected reproductive success of a reference organism." By protecting communities, the breadth of biodiversity that contributes to the persistence of the taxon of concern, in theory, is protected. This protection entails two primary design concerns: design for persistence through perturbations, and persistence with change.

Persistence through perturbation is crucial, and often predictable. Drought, floods and fire, are all events that alter the dispersion of critical taxa and also the community of which they are a part. Going back to our earlier example, desert bighorn sheep persist as metapopulations, where small populations wink out of some mountain ranges, and move to nearby unoccupied ones dependent on the highly spatially unpredictable rainfall events. Thus, not only are both occupied *and unoccupied* core sites (or nodes using network theory terminology) necessary, but corridors (or linkages) between core sites must be conserved. In many cases, for taxa of concern, these are known, but not all. Understanding the natural history of biodiversity broadly becomes important.

Environmental changes poses a distinct challenge to taxon-based conservation, but can be addressed through predicted change analyses. Climate shift, pollution patterns, and exotic species are examples of threats imposed on a taxon approach to conservation. From our examples above, California gnatcatchers and Quino checkerspot butterflies are both examples of endangered taxa that are shifting their ranges (Preston et al. 2012; Van Tassel et al. 2017) in response to environmental change. While linkages (corridors) were integrated into the plan design, these are challenging for decision-makers to grasp and often the last elements to procure in a conservation plan. With and Crist (1995) noted that designing a conservation reserve with a low fractal dimension reduces the land area needed for conservation, allowing percolation of taxa across the landscape between nodes, and the WRC-MSHCP goal incorporated corridors expressly for this goal (Allen et al. 2003).

The California Spotted Owl is an example of the importance of community in protecting specific taxa. This taxon depends upon old-growth forest for nesting. Large, old-growth stands are sensitive to severe fires, that are increasingly common as a function of global climate change, Nitrogen (N) deposition, and stand densification. But the owl is also dependent upon the San Bernardino Flying Squirrel, and other small mammals that depend upon truffle and mushroom-producing fungi, that appear sensitive to drought and N deposition (see above discussion). Therefore, conserving the entire community from climate change and poor management practices remains a critical step for both taxon based and community-wide conservation.

At a broader scale, Jimenéz-Osornio et al. (2009) noted that Mexico maintains a widespread number of large reserves throughout the country. These include reserves across the Yucatán Peninsula comprising part of the MesoAmerican Biological Corridor Project, from Celestun to Ria Lagartos, and from Calakmul to Sian Ka'an, and linking down through Central America. To further link and sustain the high biodiversity of the region, they reported that both University-based Field Stations (e.g., the El Eden Ecological Reserve) and the local populace maintains multiple small community-scale reserves for many, if not most, of the local communities. These can be for religious observances, archeological sites, or simply rotational swidden agriculture. Together, these make a powerful network of large and small, interconnected networked suite of conserved lands resulting in a Regional Conservation Strategy. This strategy can include agroforestry lands, late seral forests, and even successional patches that support both taxa of concern and places for continued evolutionary processes. Just as importantly, many regions around the world have multiple conservation reserves supporting diverse elements from plants to animals, and even to fungi.

8.6 A Phylogenetic Approach to Biodiversity

Once we have made the step from single-species approaches to multi-species approaches, is there a way to add even more information for setting conservation priorities on the landscape? We argue that there is, by expanding the definition of biodiversity to include the phylogenetic relationships of all organisms in a spatial context, a field generally called *spatial phylogenetics* (Thornhill et al. 2016, 2017). The basic idea is to turn the tree of life into a GIS layer that can then be used with other layers in objective conservation assessments.

8.6.1 Phylogenetic Metrics of Biodiversity

This field is based on concepts that were largely initiated in Australia. *Phylogenetic diversity* (PD; Faith 1992) is the central metric of biodiversity used; it is defined as the sum of the branch lengths on the phylogeny connecting all organisms in a location. It is best expressed as a percent of the total phylogeny. In other words, if 12% of the branch length of an overarching phylogeny is located in a location, its PD is 0.12. Another important phylogenetic metric is *phylogenetic endemism* (PE, Rosauer et al. 2009); it is like PD but measured on a modified phylogeny where the topology is the same but each branch length on the phylogeny has been divided by its range size. Thus narrowly distributed branches contribute most to this metric, so a place with high PE has a lot of range-restricted branches. Two further metrics were developed while one of us (Mishler et al. 2014) was on sabbatical in Australia, *relative phylogenetic diversity* (RPD) and *relative phylogenetic endemism* (RPE).

Both of these metrics are ratios comparing PD or PE measured using the observed tree, to PD or PE measured on a comparison tree where the topology is the same but each branch length is adjusted to be of equal length. Thus a location with high RPD (for example) contains branches that are longer than average.

In addition to these phylogenetic alpha diversity metrics, there is also a full suite of phylogenetic beta diversity (or turnover) metrics. These are similar to metrics used for species turnover (e.g., Sorenson and Jaccard indices) except that instead of shared and unshared species, the phylogenetic metrics use shared and unshared branches of the overarching phylogeny (Graham and Fine 2008). A pairwise matrix is built of all grid cells, then a clustering or ordination method is used to look at turnover patterns on the map.

A recent extension of both standard species-based and phylogeny-based turnover metrics (Laffan et al. 2016) takes into account the range-sizes of the species or lineages, thus applying a concept of relative endemism as described above for PE. The contribution of a species or lineage to the turnover score is inversely weighted by its range size; i.e., the smaller the range the larger the contribution. Turnover measured this way has been called range-weighted turnover, but it might more evocatively be called beta-endemism. Laffan et al. (2016) argued that this approach is better for several purposes, one of which is conservation evaluations (more below), since we are often concerned more with narrow-ranging taxa than with taxa that occur all over the map.

8.6.2 Statistical Tests

Mishler et al. (2014) also developed hypothesis tests based on a spatial randomization wherein the observed terminal taxon occurrences are randomly reassigned on the map, subject to two constraints: each grid cell maintains the same richness and each taxon retains the same range size (i.e., number of grid cells). Each of the phylogenetic metrics can be tested using the distribution resulting from many randomizations. For example, PD is tightly correlated with richness of terminal taxa in an area, since as you add more tips of the tree you necessarily add more branches. This would be particularly true if the taxa are co-occurring at random, representing the null hypothesis. Thus a grid cell that is significantly high in PD based on the randomization contains taxa that are more distantly related to each other than expected by chance (termed phylogenetic overdispersion; Webb et al. 2002). On the other hand, a grid cell that is significantly low in PD contains taxa that are more closely related to each other than expected by chance (termed phylogenetic clustering; Webb et al. 2002). Similarly, a grid cell that is significantly high in RPD contains branches that are significantly longer than average, while a grid cell that is significantly low in RPD contains branches that are significantly shorter than average. A particularly useful hypothesis test for conservation purposes is Catagorical Analysis of Neo- and Paleoendemism (CANAPE, Mishler et al. 2014). This is a two-step method to find centers of endemism and detect which are dominated by either neo- or paleoendemism. The first step is to locate cells that are significantly high (one-tailed test) in PE based on the randomization. The second step is to examine significance in RPE (two-tailed test) in those grids cells. A grid cell that is significantly high in RPE contains a concentration of range-restricted branches that are significantly longer than average (paleoendemism), while a grid cell that is significantly low in RPE contains a concentration of range-restricted branches that are significantly shorter than average (neoendemism).

8.6.3 Prioritizing Areas for Conservation

The metrics and statistical tests described above are, we argue, the best ways for characterizing biodiversity on the map. As compared to traditional spatial methods that simply use species richness and endemism as metrics, spatial phylogenetics adds a rich, evolutionary dimensionality to the picture. But while these methods are excellent descriptors of centers of diversity and endemism, some additional criteria need to be added for their application to conservation prioritization. Most important is the idea of *complementarity* (Justus and Sarkar 2002)—given what has been conserved so far, what is the maximum amount of currently unprotected biodiversity that can be protected by the next conservation action, then the next, and so on. In this way, conservation actions, often land acquisition but sometimes raising the protection status in management of existing reserves, can be prioritized to achieve maximum efficiency of time and money.

It can be seen that the turnover measures described above, particularly the range weighted version, are a critical part of the complementarity measurement. Kling et al (2018) used the California flora as a case study to develop the most sophisticated algorithm yet available to apply these criteria. They started with GIS layers for current protection status of land (using a novel quantitative scale instead of the usual binary yes/no), intactness of natural land cover (thus leaving out areas covered by urban development or agriculture), and biodiversity values (using the phylogenetic metrics described above). They then applied an algorithm addressing the question: Starting with the current protection status of the lands of California, what is the top priority grid cell to focus our next conservation efforts on, taking into account the presence of natural land cover and complementarity? This algorithm is applied iteratively; after the first action is take, the protection status and complementarity criteria are adjusted based on it, then the top priority for the second action is chosen, and so on. In this way, priority is given to poorly protected locations that have high intactness of natural land cover and high biodiversity value (i.e., contain many lineages that have small ranges and are not protected well elsewhere on the map). In summary, the overarching goal is to conserve as much of the phylogeny as possible. And to be efficient, actions are prioritized in order of how much they individually contribute to that goal.

Kling et al. (2018) further noted that the version of the phylogenetic tree that one uses to measure PD or PE gives different types of information each valuable for conservation consideration. They called these the *facets of phylodiversity* and suggested that each should be used separately with the algorithm described above. If one uses the topology where the branch lengths represent the inferred number of mutations (a *phylogram*) then PD measured on that tree is a good measure of genetic diversity in a region. If one uses a topology where the branch lengths have been scaled to time (a *chronogram*) then PD measured on that tree is a good measure of the amount of evolutionary survival time represented in a region. If one uses the topology where the branch lengths have been adjusted to all be the same length (a *cladogram*) then PD measured on that tree is a good measure of the net amount of diversification (speciation - extinction) represented in a region. Each facet gives a different yet important view into the history of the lineages in a place. In their case study of the California flora, Kling et al. (2018) looked at the prioritizations suggested by all three facets, and argued that the very top priority grid cells were ones that score high in all three.

This algorithm can be applied anywhere, on any scale, as long as there is a decent phylogeny of the organisms under consideration and good distributional information about the tips of the phylogeny. So far only applied to plants, it should be applied to animals as well, not to mention to microbes (see below). In addition, the algorithm should be extended beyond the factors that Kling et al. (2018) examined, for better priority setting, e.g., by adding GIS layers of land prices, threats from urban and agricultural trends, and predicted climate change.

The field of phylogenetic conservation biology is in its infancy and is worthy of intensive development to meet the current crises affecting biodiversity via land use changes, invasive species, and climate change. Including the history of biodiversity in conservation assessment helps us predict and assure its future.

8.6.4 Adding Microbes to the Mix

Microbial data, as for example gathered in metagenomic studies, is ideally suited for this phylogenetic approach, as species designations are particularly arbitrary and phylogenies readily available. This approach provides a means to include microbial groups when determining areas that are critical to protect. Today, most surveys of microbes, from Archea to fungi and nematodes, are based on DNA sequencing, not on morphological fruiting or feeding structures alone. The NEON program and many different studies, such as surveys on Mount St. Helens, are transitioning from morphological identification (Allen et al. 2018; Maltz et al. 2020), are undertaking wide-ranging assessments of microbial diversity. By studying particular perturbations, changes in phylogenetic metrics can be identified. For example, ectomycorrhizal (EM) fungi comprise a phylogenetically diverse suite of critical symbionts for trees. The different groups independently evolved, and each has a different suite of traits important to tree production and stress tolerance (Allen 2022). For example, in the San Bernardino Mountains, 145 different EM fungal taxa were sequenced (using the ITS region of the nuclear rRNA) from roots of *Pinus ponderosa* with different levels of N deposition and fertilization (Sirajuddin 2009). Some taxa were quite tolerant of N levels, such as the Thelephoraceae, a group well known for drought tolerance as well. Others, including taxa of *Rhizopogon*, a group known to be important in the mammal and owl food chain, and *Russula*, a common late seral taxon, virtually disappeared with N deposition or fertilization (Fig. 8.3). Protection of the fungal clades crucial for pines, flying squirrels, and spotted owls, by reducing air pollution, could play an important role for conserving biodiversity across the region.

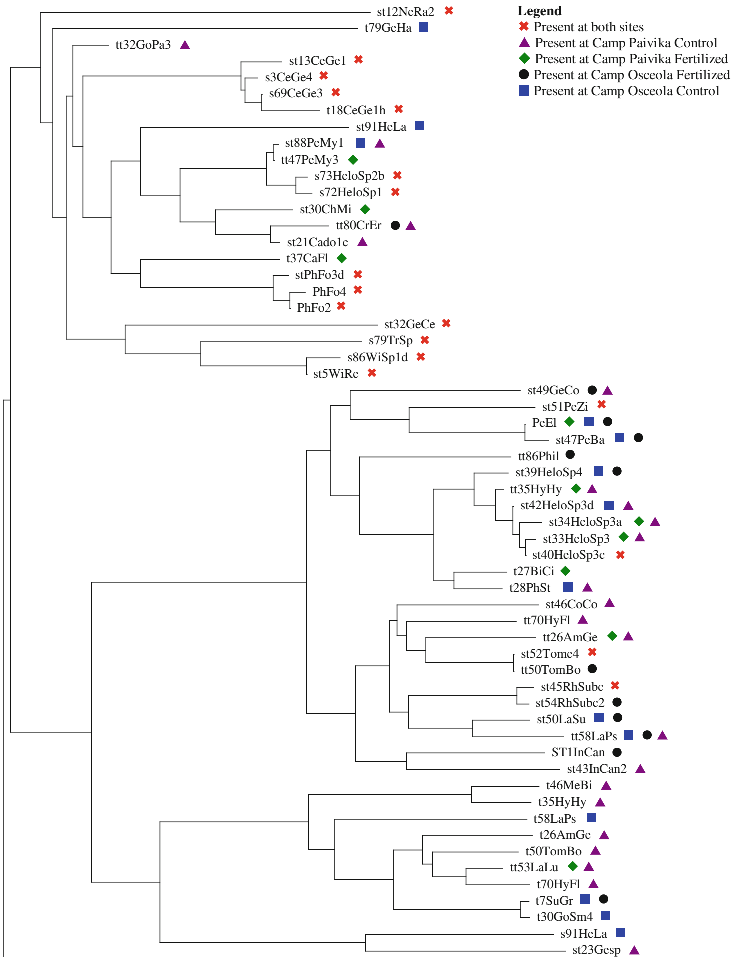

Fig. 8.3 Ectomycorrhizal fungal site phylogeny and responses to N inputs (data from Sirajuddin (2009). Fungi were sequenced from ectomycorrhizal root tips of *Pinus ponderosa* in the San Bernardino Mountains USDA Forest Service research plots from the internal transcribed region of the nuclear rRNA. The blue clades are found only where N deposition was low, and no N fertilizer added

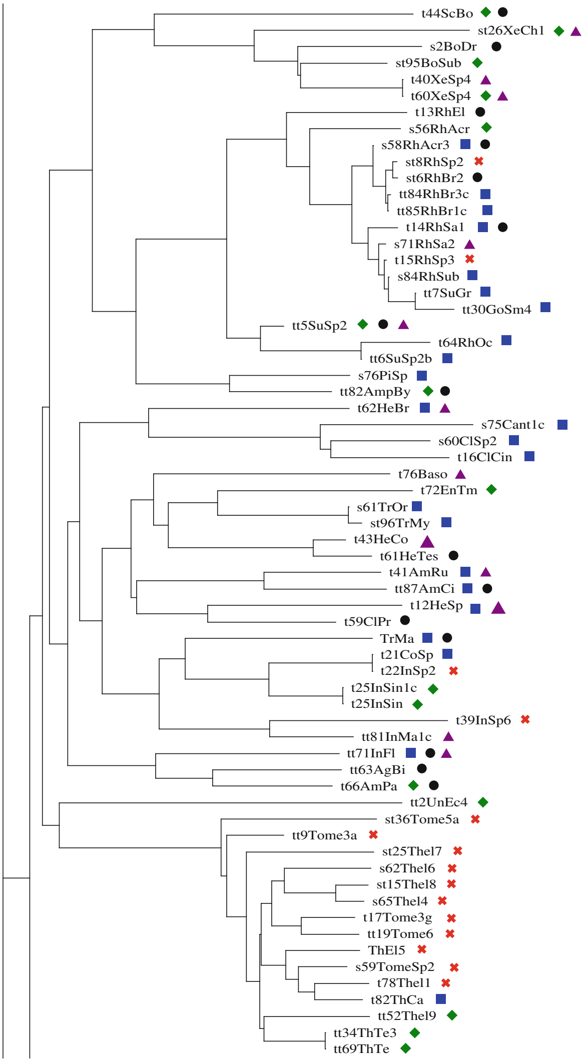

Fig. 8.3 (continued)

8.7 Synthesis and Summary: Integrating Evolutionary and Ecological Processes

Populations arise and some go extinct while others thrive—that is the essence of biodiversity. But mass extinction is of serious concern. While mass extinctions have occurred naturally in earth history, the current mass extinction is caused by the activity of one particular species, *Homo sapiens*. Given the current crisis and the urgent need to decide on conservation priorities immediately, probably the best approach to

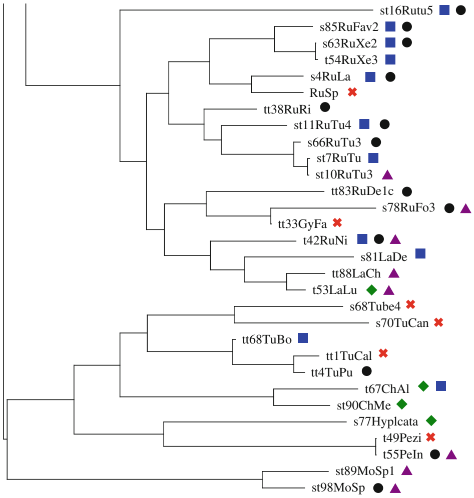

Fig. 8.3 (continued)

protecting biodiversity is not the protection of individual taxa one at a time. Instead, we have the tools to protect the geographic locations within which biodiversity as well as individual taxa of concern can persist and evolve. Biology is not static, but dynamic. Populations of organisms, communities in which they interact, and ecosystems in which they live, all change constantly. Ecosystems undergo climate change and change due to particular taxa.

To protect biodiversity, we must use all the tools we have to identify and protect landscapes that allow for future dynamics, not just the conditions of the past and present.

None of the approaches described above are mutually exclusive. We propose that the field should integrate the phylogenetic approach described above into reserve design built around multiple species habitat conservation plans (MSHCP), incorporating conservation principles of reserve design and ecosystem services (Allen et al. 2003). These approaches are cost effective, ecologically effective, and allow for evolutionary processes to continue supporting all biodiversity.

While protecting biodiversity, we are at the same time protecting ourselves. The emerging topic of ecosystem services clearly defines crucial benefits to humans for wildland protection. These include sequestering C, water purification, and pollutant mitigation. Much of the land managed by the US Forest Service in California was protected as a watershed for drinking water. Other recreation areas like the San Joaquin Wildlife Refuge is designed to use reclaimed water for wildlife, including species of special concern such as the White-faced ibis, a migratory species, and burrowing owls and tricolored blackbirds, around the large, seasonal wetland, Mystic Lake. Finally, protecting lands containing unique biodiversity maintains lands that sequester CO_2, as opposed to shifting these lands to developments that release greenhouse gases.

In summary, we gain as a species, biodiversity gains broadly, and we improve the stage for the future when we use all the tools, phylogenetics, ecology, and ecosystem services with emerging molecular and geospatial tools now at our call. Scientifically, we can certainly pivot; but can the political environment move as quickly?

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Part IV
Sustainability and the Future

Chapter 9
Energy and Society: Toward a Sustainable Future

Saul Griffith

Abstract Energy is the single greatest lever that moves civilization. As a society, we have pulled upon fossil fuels as a historical source of energy, but have begun transitioning toward alternatives. This chapter explores our global move toward alternative forms of energy, their feasibility and impacts, and the kind of world we can create with a decarbonized and electrified future. We thus need to consider how much energy we need, and evaluate alternative sources of energy including nuclear power. Then we need to consider what the effects of achieving a sustainable energy future would be, including impacts on biodiversity and land use. These goals will aid in creating a sustainable civilization while mitigating the destruction of biodiversity and further impacts to planetary life support systems.

9.1 Introduction

Collaboration, tool making, tool use, and even trading have all now been identified in non-human animals. Our species is less special than we think. One unique thing we might still lay claim to is the use of novel ways to harness larger energy sources that magnify our strength and give us superpowers. Pelicans and albatross use the winds to soar, dolphins the power of the wave to surf, plants the power of the sun to grow, and all creatures are ultimately powered by solar energy. Humans, however, appear to be unique in harnessing and controlling these energy sources at a planetary scale, adding buried fossil fuels and even nuclear power to the mix.

Our superpower began with learning to tame fire, where we could harness energy beyond our metabolism to improve our chances of survival. This enabled us to derive more calories from food, to develop culture, and to extend our daylight hours to become a species that transcends ideas of the diurnal or nocturnal. We tamed the cold and the night. Fire and tools led to machines that helped us with agriculture, construction, entertainment, and war. For the machines to be more powerful, they needed to harness more than human energy, so we gave them the labor of other

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species—the ox, the donkey, the horse—and then the power of wind, water, eventually fire and steam, and then combustion engines.

It appears we have always learned how to exploit resources before we understood their consequences and how to manage them wisely. Fire gave us deforestation. Fossil fuels gave us water pollution, air pollution, damage to ecosystems, and perhaps most existential of all, climate change. Our division of the world by roads for our vehicles has disrupted ecosystems globally and fragmented the habitats of wildlife. In the contiguous United States, you are never more than 22 miles from a road, a long day's walk. Many of our wild places feel like zoos—crisscrossed by four-wheel-drives—only the perimeter fences are farther off.

Our flirtation with atomic energy thrust upon us multi-generational waste management problems, and the proliferation of dangerous materials problems. It also has increased the risks of another existential challenge—nuclear war—or even just the more mundane terror of nuclear plant meltdown. As yet we have made no real effort to suggest that our capacity to harness much larger sums of energy than we use is anything but selfish, purely for our benefit.

Our pets may have benefited from warmer places to sleep but our livestock are more enslaved than ever, and might be considered part of our large industrial machine. One of the key units with which we talk about energy and power refers to our casual subjugation of another species—horsepower. Perhaps we can hope that our capacity to harness energy in excess of our personal needs means that we could harness some of the energy in cleaning up the problems we have created but surely this will only be arrived at if we recognize our interdependence on the health of all of the other species. You can imagine that we might dedicate 10% of energy production to righting environmental wrongs—a tithe for the earth perhaps—by cleaning waterways, filtering microplastics, restoring forests, and stabilizing our climate, but we haven't risen to that level of interspecies collegiality yet. The waste heat and waste emissions of our energy systems are all that we give to ecosystems so far, a long shot from using a relevant amount of our energies to rejuvenate them and support the other species that indirectly support us.

With the irrefutable evidence of climate change caused by our consumption of fossil fuels, we are for the first time grappling with the consequences of the scale at which humanity now operates. It is indeed the Anthropocene. Our species and our stuff will be the dominating layer in the geological record of our age. Relatedly, we are now understanding our impacts on biodiversity and the risks that collapsing biodiversity poses for our species. At some scale of awareness much larger than academia or even environmentalism, we recognize that the ways we find, transform, move, process, and use energy will not enable our species, let alone other species, to thrive beyond this century. We need to reckon with how to provide the energy that defines a good life, at what consequences, and in so considering the effects on other species for the first time we must consider what a balance might look like.

Or otherwise stated: how will we live and how will we power those lives in a manner that leaves room for biodiversity to thrive, such that we might thrive long enough to find out not only what our species can achieve, but what interspecific equality and generosity might bring?

This returns us to speciesism and our self-interest. This contemporary framing forces us to confront the essential question of balancing our energy use desires (which are far beyond our needs) with our need for a healthy planetary system.

To discuss the future of energy is to discuss balance, and to face a host of uncomfortable questions about limits. This conversation about limits is old, back to Malthus and beyond. It was very much part of the environmentalist conversation of the 1970s, in the shadow of *Silent Spring* (Rachel Carson), *The Population Bomb* (Paul Ehrlich), and *Limits to Growth* (Club of Rome). John Holdren captured it with the brevity of a physicist in, *Energy; a Sierra Club Battlebook.*

> In a hypothetical world, free of the constraints of biology and thermodynamics, such thorny, socioeconomic questions might not have to be asked at all; the energy problem would be reduced to the technical details of meeting any demand that happened to materialize. Unfortunately, we do not live in such a world. Energy is not merely the prime mover of technology; it is also a central ingredient in man's impact on his environment. No means of supplying energy is without its liabilities, and no form of its consumption is without consequence to the ecosystems that support us.

Holdren, speaking of the 1970s energy crisis, goes on to say,

> … it serves to suggest that there are no easy solutions to the so-called "energy crisis."

And that was before we understood what climate change had in store for us.

9.2 History

We should probably start with what we know, or what we think we know.

Many treatises on energy and humans start with graphs (e.g., Fig. 9.1) of how our fuel use has evolved over the last few hundred years and show how we went from biomass to biomass-plus-hydro, to bio-plus-hydro-plus-coal, etc., with an ever-rising "exponential" increase in the energy use of humans. It is this ever-increasing demand for energy that concerns experts about how to balance our energy needs with constraints such as climate change, air quality, and the habitat of other organisms. The first fuel to amplify our impact was biomass—trees, something we have been using at a planetary scale for thousands of years.

We are now aware that much of the denuding of the Mediterranean was to build the infrastructure to run the hot baths of Rome; the cedar tree that adorns the Lebanese flag required protective conservation efforts running as far back as the Roman Emperor Hadrian. There is little if any wild forest left in Western Europe because of our energy use patterns, agriculture, and war. 95% of American forests have been lost.[1] Half of the world's biomass, mostly forest, equivalent to more than 1 trillion tons, is already lost (Elhacham et al. 2020).

Then in the nineteenth century, we found deposits of old biomass and learned to exploit them, too. First came coal, with the accompanying and enabling invention,

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[1] https://www.saveamericasforests.org/resources/Destruction.htm

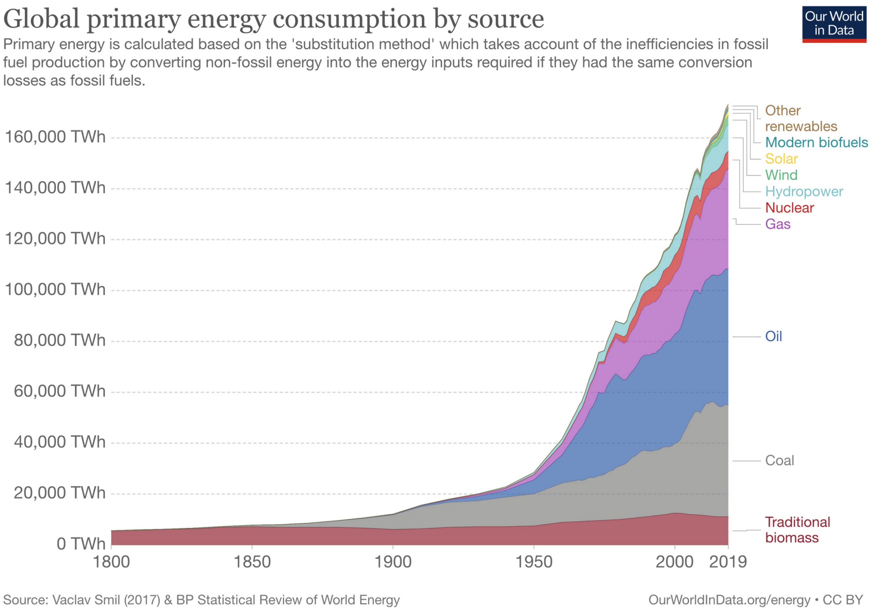

Fig. 9.1 200-year history of global primary energy consumption

the steam engine. This use steadily increased through 1900, when we first started using oil at scale. “Town gas,” known nowadays as natural gas, followed close on the heels of oil in ramping up through the twentieth century. By the middle of the twentieth century, fossil fuels were dominant, and our awareness of the problems they would present in terms of both air pollution and climate change were clear enough that by 1965 they made it to the U.S. President’s desk (Restoring the Quality of our Environment 1965).

This happened just as excitement around the peaceful uses of atomic energy was heating up, and many people imagined and advocated for huge quantities of nuclear power, some famously calling it “too cheap to meter.” In *Understanding the “National Energy Dilemma*,” (Understanding the national energy dilemma 1973) a document prepared for the Joint Committee on Atomic Energy, it was projected we would be using more than 100 Quads of non-fossil (implied nuclear) energy in the U.S. by 2050. This is more energy than the whole country uses today. Similar enthusiasms for enormous quantities of nuclear energy were not confined to the United States. Concerns over radioactive waste management and high-profile reactor accidents like that at Three Mile Island in 1979 tempered the general enthusiasm, and nuclear power has not grown at anything like the rate we once thought it would.

Hydroelectric power, a descendant of our early water wheels, also ramped up considerably during the latter half of the twentieth century as our capacity to build giant infrastructure projects and the ability to structurally engineer enormous concrete dams developed. Hydroelectric power is still our largest renewable energy contributor, though the best hydroelectric sites have mostly been exploited already, and new hydroelectric resources generally conflict with other environmental concerns including ecosystem destruction, population displacement, and water management.

Out of the multiple energy crises of the 1970s came a renewed interest in renewables, notably wind and solar, but also geothermal, wave, tidal, and biofuels. After three decades of being expensive niche energy sources, wind and solar started to compete economically at the turn of the twenty-first century, and only two decades later are often the lowest-cost energy option for new power plants. The advantage of fossil fuels is too great, the advocates say, their energy density (how much bang they give us per pound or kilogram) and their inherent property of being convenient storage mechanisms will mean we can never replace them. In the opposing camp, a century of steady developments in batteries has bridged this gap, and we can now imagine huge quantities of batteries storing yesterday's sunlight for tomorrow's trip to the grocery store and last week's wind energy for next week's home heating.

We haven't stopped burning our original fuel (trees and biofuels), and in fact, we are using as much as ever. In the developing world, it is still used as firewood and heating fuels, with associated health and air quality problems. Comparatively, in the developed world, we now dedicate crops and residues from the paper and pulp industry as significant contributors to our energy systems. This creates tensions among land use, soil quality, and energy. These tensions might be further complicated by proposals to create "negative emissions" by using biofuels to create energy while CO_2 emissions are captured and buried deep underground. This Bio Energy and Carbon Capture and Storage (BECCS) is one of many negative emissions technologies that we now rely upon if we wish to stabilize the climate at or below 1.5 °C[2] by the end of the twenty-first century. The quantity that we must bury in these low-emission scenarios is at the very limit of what informed people consider possible.[3] Indeed, we are forewarned that at the scale of 10 gigatons or 10 billion tons per year, the land use requirements will interfere with our other wants and needs including agriculture and forests. For perspective, we pull about 10 gigatons of fossil fuels out of the ground each year—more than a ton per person—and to imagine we will build an industry as large as the existing fossil fuel industry to pump its waste back into the ground may be the most tragic symbol of our hubris.

For perspective, as shown in Fig. 9.2, around 20% of all things that humans "move" each year are fossil fuels extracted from the ground. Once we bring those fossil fuels to the surface, we oxidize them. Since that means adding two oxygen atoms to each carbon atom, we increase the weight of carbon dioxide to be approximately half of all things we move each year. CO_2 is our single most prolific byproduct, all exhausted into the thin layer of atmosphere that we share with the rest of biodiversity on this precious rock floating through space.

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[2] Compared to pre-industrial levels.

[3] https://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliablesequestration-a-research-agenda.

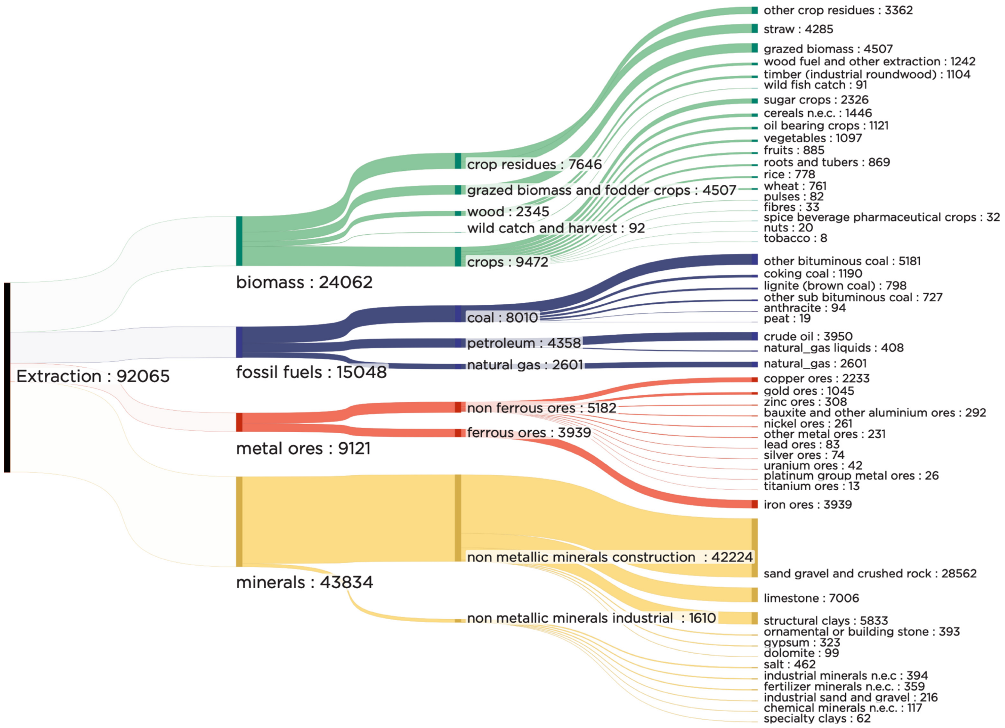

Fig. 9.2 Annual global material flow estimates, in millions of tons per year (by the author)

Projections of historical energy-use numbers have been a common theme in treatises that complicate the future of energy. Such projections included factors or ratios that attempt to find the right multiplier for our population per capita energy use to project how much energy we need, but they all over-predicted our future energy use by orders of magnitude. This happened for many reasons; to name a few: over-estimating population growth, over-estimating the growth of energy consumption per capita, under-estimating the technological gains of efficiency, and nuclear techno-optimism.

9.3 On Fossil Fueling Our Species

Vast amounts of human labor, economic activity, and land are dedicated to finding, mining, refining, transporting, supplying, and consuming energy. Yet these inputs are hidden from us as the conveniences of modern life masque the dirty reality of those fuels. As you stand next to a car as it is filled with petroleum, you are probably not cognizant that you are pouring a volume of liquid as large as yourself into that vehicle, only to promptly burn it. Very few people are aware that a considerable proportion of rail freight is moving coal from mines to power plants—processes and machines that are nearly invisible to most of us. We just experience the convenience of electricity at the end of the plug. Fossil fuels are nearly a quarter of all materials humans move every year, including dirt and soil; though this jumps to half if we consider the CO_2 that results from burning those fuels. We move more CO_2 every year than we do every other physical material that our society is built from. No wonder the atmosphere is full of it. The average American in 2020 used directly and indirectly about 6000 kg or 6 tons of fossil fuels. If our daily allowance of fossil fuels were something we had to leave the house with, then our backpacks would weigh close to 40 lbs. What is amazing is how well we have hidden these flows of materials from ourselves. With ignorance, we don't even need denial.

For illustration, America consumes around 20% of the world's energy. The footprint of the supply chain is breathtaking: 700 million tons of coal is mined from 669 coal mines which feed tens of thousands of coal cars that are pulled from their mines to 241 power plants by thousands of diesel locomotives over 140,000 miles of freight rail track.

27 trillion cubic feet of natural gas is pulled from a few hundred offshore drilling rigs and close to a million terrestrial gas wells. The gas is moved through 321,000 miles of natural gas transmission lines, an effort that requires close to 1% of U.S. energy flow. Some of it is moved through 121 Liquid Natural Gas terminals and stored for later use in 400 underground caverns that are geological formations suitable to the task. They mostly don't leak. Much of that gas is burned in 2000 gas-fired electricity generation plants, but much of it is further pumped through 1.32 million miles of gas distribution lines to connect to 69 million homes and 3 million commercial buildings that use gas for water heat, space heat, cooking, and other activities.

300 billion gallons of oil are drilled from close to a million wells, pumped by derricks, and delivered through 224,000 miles of pipeline and around a hundred oil

tankers to 135 oil refineries that convert it to gasoline and diesel that is trucked by 100,000 tanker trucks to 150,000 gas stations to feed 265 million cars, trucks, and motorcycles.

And that is just in America. Early into the twenty-first century, we passed the mark of 1 billion cars in operation on the planet. Some people project we'll get to 2 billion by mid-century.

One reason given by the fossil fuel industry to convince us not to switch to renewable energy is that the solar panels and wind farms will take up too much space, yet they do not count the incredible footprint of fossil fuel supply chains. If we covered a similar area to all of the land consumed by fossil fuel pipelines and coal-carrying railroad tracks, we would supply a similar amount of energy to the fossil fuel industry. In both cases, it is a few percent of the total land surface.

When thinking about our energy use, past or future, one cannot avoid thinking about its intersection with land use and material use, and its environmental effects on biodiversity. In looking to the future of energy for our species, we must inevitably confront these trade-offs.

9.4 Energy System Trade-Offs

We are already aware of the environmental trade-offs of fossil fuels. Coal mining has led to mountaintop removal and subsidence around mine sites. Enormous amounts of coal dust are liberated on every coal-train's trip from mine-site to power-plant. Heavy and sometimes radioactive metals surround the countryside down-wind of coal plants. Oil slicks are common to leaking pipelines and to oil-tankers such as the Exxon Valdez. Accidents such as the Deepwater Horizon drilling accident and the burning oil wells of Iraq and Kuwait fill our minds with what can go wrong.

Coal replaced sail (wind power), not so much because it was cheaper, nor because it was faster, but because it was more predictable, and the emerging industrial economy wanted predictability. The coal ships were not so much faster than the sailing schooners that prevailed at the time, but they needed less skilled labor and were easier to schedule. In this anecdote we can see the trade-offs in time and human labor embedded in the way fossil fuels changed the way we do things. The speed of freight transport has only increased marginally from 10 to 15 knots in the last century, and we could choose to slow things down again to 10–12 knots, which would allow for (largely autonomous) solar-and wind powered freight. However, it appears that people are hell bent on the higher speeds that a heavier density fuel allows, thus pushing hydrogen and ammonia as potential shipping fuels.

At the turn of the century, we fretted about dwindling supplies of natural fertilizer—guano—and the devastating impact it would have on our agriculture and growth. The Haber–Bosch process and synthetic nitrogenous fertilizers were the result. This process, critical to modern agriculture and productivity, uses 1% of the world's energy supply and produces 1.4% of CO_2 emissions. 7% of our greenhouse gas emissions are nitrous oxide, N_2O, the majority from these same fertilizers.

These fertilizers cause algal blooms and vexing environmental problems, including the monoculture industrial agriculture that resulted, but the alternatives require more labor and would increase the cost of food which is seen as an intolerable compromise by many.

Nearly 10% of the world's energy is now used in the service of finding, mining, refining, and transporting our fossil fuels and other energy sources. This number, sometimes known as Energy Returned on Energy Invested (EROI), gets higher each year as the fossil resources get harder to reach and lower in energy content.

This is not to say that solar and wind won't also have trade-offs. Industrial solar farms amount to a cropping monoculture even worse than industrial agriculture in their effects on local biodiversity. Wind farms interfere with birds and insects. Hydroelectricity can destroy the ecosystems in the catchment area and dam basin. Advocates for the market sorting out these compromises are many, but mechanisms (e.g., a carbon tax) that "price in the environmental externalities" remain more theory than practice. We still don't have terribly effective mechanisms for the exchange rates between dollars and degrees of climate change, let alone dollars vs. toxins vs. biodiversity destruction vs. climate vs. human flourishing. This is the extremely difficult moral calculus that vexes such proposals.

9.5 Predicting the Future

When we first started collecting energy data in response to the 1970s oil crises, there were many projections into the future of what demand would be, and these turned out to be far higher than we have actually seen. In a report commissioned by the Joint Committee on Atomic Energy, the Senate committee then tasked with understanding U.S. energy needs and futures—"Understanding the National Energy Dilemma" (Bridges 1973)—used forecasts into the future that would have had the U.S. using 100 quads by 1985, 160 quads by 2000, and more than 200 quads by 2050 in the "minimum" case. Such was the promise at the time of nuclear energy and the limitations of modeling using simple exponents. In 2019, the U.S. used 101 quads, and in 2020 used 92.

"Understanding the National Energy Dilemma" (Bridges 1973) might be seen as the techno-optimist viewpoint of the future; the Club of Rome's more sanguine "The Limits to Growth" (Meadows et al. 1972) was the sober opposite. Experts can still be found on either side of this divide, but with climate change, we realize the limit is likely not energy per se. Instead, it is about finding an equilibrium temperature that allows ecosystems and biodiversity to thrive, and for humans to settle into curating the atmosphere, thus balancing our need for biodiversity with the land-use demands of energy, agriculture, housing, and leisure.

It is clear to many that we must figure out how to be the competent gardeners of a planet earth. As Bill McKibben famously argued in "The End of Nature," (McKibben 1989) as a result of anthropogenic climate change, we now hold the fate of all other species in our hands. This makes trying to predict the future of energy far less important than acknowledging that the only viable option is to figure out how to succeed in managing the trade-offs. Either we create a balanced garden planet with humans actively involved in limiting our footprint, or we risk undermining the conditions under which humanity can coexist with all other species.

9.6 How Much Energy Do We Need?

The answer to this question is very dependent on the type of energy we will use in the future, and enormously dependent on where it comes from. Historically we speak of energy needs in units of primary energy—the energy content per ton of coal, per cubic foot of natural gas, or per barrel of oil.

The precipitous fall in the cost of batteries, and the emergence of viable electric vehicles, has enabled renewable electrification to seriously contend with fossil fuels. One convenience of fossil fuels is that you can store a lot of them, for a long time. At any given moment, a month or two's supply of oil, coal, and natural gas is sitting in stockpiles, strategic reserves, and storage caverns. This storage allows us to get through winter, a stormy night, or supply chain shortages. Contrariwise, electricity must be used practically instantly the moment it is generated. But now viable batteries exist that can store electricity for days and weeks. With hydrogen, ammonia, and fossil fuel substitutes known as "electrofuels" (produced with excess electricity), we can now imagine storing electricity for the winter. Yet we must design our energy system for the winter, when solar insolation is the lowest. It might mean we have excess supply in the summer, but it is excess supply that has enabled the fossil fuel industry to balance supply and demand for the last century.

Why is this important? Because electricity is far more efficient than fossil fuels or chemical fuels. For example, with 1kWh of coal, by the time I burn it, run it through an electricity generator, and turn on a light bulb, I only get about 1/3 of a kWh of electricity powering my bulb. With natural gas, I might do better and get 1/2 of a kWh. Yet if I have solar-generated electricity stored in my battery then close to 90% of my original kWh might power my lightbulb. This efficiency advantage of electricity is true in all areas of energy. An electric vehicle uses approximately 1/3 or 1/4 of the energy of an equivalent internal combustion engine because it isn't generating waste heat. A wind turbine or solar cell may not absorb all of the energy from the wind or sunshine, but it doesn't create huge quantities of heat. The heat pump is another kind of electric technology that harnesses more energy from its surroundings than is fed to it with electricity. It can take air that feels cool and separate it into a small parcel of hot air and a large parcel of cold air. These heat pumps allow us to use 1 unit of electricity to generate 3 or 4 units of heat. This is far more efficient than using 1 unit of natural gas in exchange for 0.8–0.9 units of heat. Studies of global energy systems that look at high degrees of electrification powered by renewables (and even some nuclear) show that we could have all the energy benefits of our current lifestyles at less than 1/2 the energy input compared with fossil fuels.[4–5] The average American uses the equivalent of 10 kW of power (a constant flux of 10 kJ of energy use per second) to power their life. The average southern European uses around 4 kW. The average Indian or African uses under 1 kW. Activist communities in Switzerland have tried to live on a self-imposed budget of 2 kW.[6]

It should be noted that energy economies owe more to fossil fuels than anything else. The International Energy Agency sounds very fancy but was founded as an organization of oil-producing and consuming nations. It isn't exactly unbiased in the presentation of world energy futures. Indeed, many people look to Shell or BP or other fossil fuel-based companies for their energy economy forecasts, which struggle to look far beyond the status quo. The world energy economy is often described in Quads, or quadrillions of British thermal units, or MBOE (Millions of Barrels of Oil Equivalent). The S.I. units of energy are Joules and Watts. One is a unit of energy (the Joule), the other a unit of power (the Watt)—a rate at which something consumes power. We will know we have succeeded in an energy transition when the units we use to describe energy no longer refer to fossil fuels.

If we don't all develop a penchant for flying cars and annual round-the-world-by-jet-plane holidays, then we can see pathways toward a high quality of life existing at 2–5 kW per person. The rate of growth of the world's population has fallen much faster than most experts predicted, and indeed, 10 billion people is starting to look like the peak of our global population. Many countries have negative natural rates of population growth; and more education, particularly for women and girls, is stemming run-away population growth. 8–10 billion people consuming 2–4 kW of constant energy with high degrees of electrification does not seem impossible. This implies a 15–30 TW world, which is not hugely different from the ~20 TW world powered by fossil fuels today.

One can still find many libertarians or ideological conservatives who will argue that we can only thrive as a species if we have an abundance of cheap energy that enables us to meet every need and want, including reaching for stars with space travel. Many indigenous cultures found stability for thousands of years in societies that had enough energy to build lively cultures and even animus religions that balanced their needs with the species they relied upon for food. Whether the cultural balance falls towards societies that can balance their needs with those of other species or towards societies that believe God will provide and so ignore physical constraints and other species, will probably determine our fate.

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[4] https://web.stanford.edu/group/efmh/jacobson/WWSBook/WWSBook.html.

[5] https://mitpress.mit.edu/books/electrify.

[6] https://en.wikipedia.org/wiki/2000-wattsociety.

9.7 Where Will All Our Energy Come From?

The good news is that we have no shortage of energy. The amount of solar radiation that makes it through the atmosphere and into our earth system is 85,000 terawatts. A terawatt (TW) is a trillion watts, or about the same power as one hundred billion LED lightbulbs. The amount of solar that hits the earth thus far surpasses the ~20 TW that we currently use, as well as our projected 15–30 TW electrified world.[7]

A summary of the potential of renewable or natural sources of energy is given in Fig. 9.3. The sun is the primary source of almost all our renewables—energy that can be replenished. The major player is **solar** (85,000 TW) and it is abundant wherever the sun shines. The sun heats the air and creates **wind** (3600 TW at all altitudes, around 400 TW that can be harnessed with turbines). The winds whip up **waves** (62 TW deep ocean, 3T W on coastlines) that can be captured by wave power generators. The sun evaporates water, which becomes clouds and rain, filling rivers that can be tapped for **hydroelectricity** (7 TW). As your feet know when walking on hot sand on a summer beach, the sun also heats the ground. This "ground-source" geothermal heat can be harvested year-round by a technology called "heat pumps" to keep buildings at an even temperature. Confusingly, this kind of geothermal energy differs from what people commonly think of, which is a closer relative of geysers and volcanoes and hot springs, and thus rare. **Geothermal energy** (32 TW) is not derived from solar but is remnant heat left over from the formation of the earth, with a little heat generated from radioactive decay thrown in for good measure. This creates extremely hot rock, which is accessible by drilling and can be used to create steam,

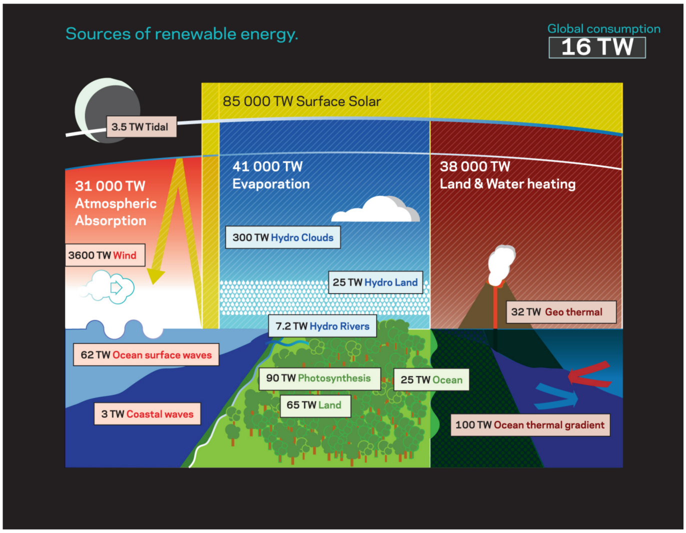

Fig. 9.3 Global renewable and natural energy flows *Source* by the author

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[7] tntcat.iiasa.ac.at/PFUDB

driving a turbine to create electricity. The temperature difference between the top and the bottom of the ocean could also create energy in the **ocean thermal gradient** (100 TW) but it is a small temperature difference that is very difficult to harness efficiently.

The sun is also critical to photosynthesis, which creates biomass (wood, algae, grasses, forestry and agricultural waste, food waste, human waste, and other biological matter) which can be converted to **biofuels** (65 TW in all land based bio, and 25 TW in the ocean) to supply energy to hard-to-decarbonize sectors like long-haul aviation. All of our fossil fuels are incredibly old biofuels that have been buried and concentrated over time. It is estimated that fossil fuels accumulate at a natural rate of 0.01–0.05 TWh. about 1000 times slower than the rate at which we use them.

Nuclear energy isn't renewable—there is a finite amount of fissile material in the world (primarily types of plutonium and uranium) (Fetter 2009). Estimates vary between 200 and 1000 years, depending on what portion of the supply it will meet, and whether we stick with light water reactors that don't produce weaponizable byproducts or whether we move to breeder reactors that do. Although we could get by without nuclear energy, it is available to us, and useful in places that don't have enough land area to support wind and solar infrastructure.

9.8 The Impacts of Our Energy Options on Biodiversity

We have a host of energy options. Let's pause to contemplate what they are.

As we saw above there is enough solar energy, or wind energy, to power all of humanity's energy needs in perpetuity if we assume that we are a highly electrified world and the total number is 15–30 TW. We could also power it for quite a long time, centuries at least, with nuclear power. In reality it will be a mix.

Given our needs, we'll have to make electricity wherever we can—understanding that some sources are easier, cheaper, and more convenient than others. Some places have better wind, some have better solar, and some don't have enough of either and will probably need some nuclear or long distance transmission of renewables from somewhere else. Where there are rivers, hydroelectricity, which provides nearly 7% of electricity in the U.S. today, and 16% globally, will be critical. Where there are oceans, wave and tidal power will help at the margins. Offshore wind is likely to be the big producer from the oceans, particularly in places with relatively shallow (50 m) continental shelves.

Solar, wind, and nuclear are the resources we have that far exceed our demands. Solar and wind are the cheapest and have fewer complications than nuclear energy. There is so much money in the fight over the future of our energy supply that an enormous brouhaha emerged in the climate and energy world when Mark Jacobson (Hanley 2018) of Stanford University and some colleagues proposed that the world could run 100% on Water, Wind and Solar (WWS) (Jacobson et al. 2015). The critique (Clack 2017) was vicious, and even by academia's petty standards, the rebuttal was even more vicious (Jacobson et al. 2017)[8]. It ended in a lawsuit. I believe history will side with Jacobson, and that we will be able to do this—others agree with me (Mai et al. 2012). Much of the critique is that we can't have reliability in an all-renewables world. There is every reason to believe it's easier than we think to turn these intermittent sources into a reliable energy supply. You do have to think about supply and demand, and my critique of this academic storm is that all should have paid more attention to both sides of the equation. Jacobson may be too anti-nuclear, but his critics are too anti-future.

We are blessed with enough zero-carbon energy to meet our needs and even expand our wants; we just have to harness that energy sensibly while minimizing potential harm to biodiversity caused by flooding river valleys for hydroelectric dams and destroying desert habits for solar developments. For example, rooftop solar is far less damaging to biodiversity than destruction of precious remaining natural habitats.

Regardless of the minutiae of exactly how we decarbonize, electricity will power civilization, and solar and wind will do the heavy lifting. The no-regrets pathway to quickly transform our fossil-fuel-powered world to a world powered mostly by electricity is a combination of a majority of renewables (solar, wind, hydro, geothermal) with moderate nuclear and some biofuels as a backstop. The balance of those things will vary geographically and can be determined largely by market forces and public opinion about how to use land. The balance of power (energy nerds are always good for an energy pun!) will be determined by how well we use storage to smooth out the variability of renewables.

9.8.1 How Much Land Will We Need to Use?

Our landscapes will look different when we make this switch to renewable energy. Solar panels and windmills will become pervasive in our cities, suburbs, and rural areas. To power all of America on solar, for example, would require about 1% of the land area dedicated to solar collection—about the same area we currently dedicate to roads or rooftops (see Figs. 9.4 and 9.5). Our rooftops, parking spaces, and commercial and industrial buildings can do double duty as solar collectors. Similarly, we can farm wind on the same land that we farm crops.

In round figures, to electrify the whole U.S. economy we'll need to generate 1800 GW. To generate all of that with solar would take about 15 million acres of solar panels. You can check our numbers: we assume a real fill fraction of 60%, a capacity factor of 24%, and a cell efficiency of 21%, so to get 1800 GW we need 15 million acres, or ~1 megawatt/acre. To harness the same amount of energy with wind power alone would take around 100 million acres planted with wind turbines. For reference, the U.S. covers 2.4 billion acres.

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[8] Dr. Staffan Qvist. https://www.vibrantcleanenergy.com/wp-content/uploads/2017/06/ReplyResponse.pdf

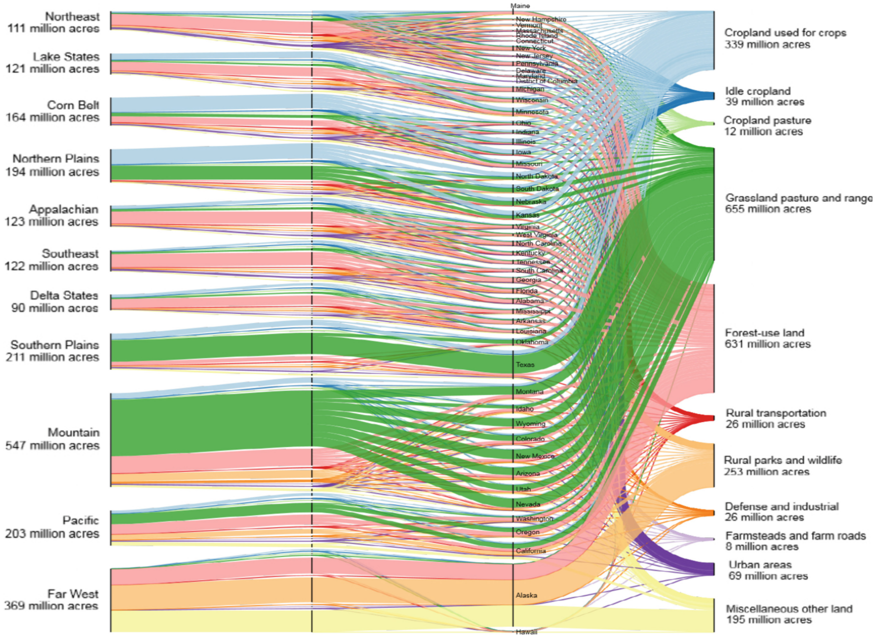

Fig. 9.4 Land-use by state in categories defined by BLS *Source* by the author

Some people talk about the size of the solar cell we will build in the center of the Arizona desert, and how it will power all of America. But that's not actually how this job will get done because of the expense of transmission (long distance) and distribution (short distance), not to mention the destruction of biodiversity that would be required. The installations will be everywhere, so it is more illustrative to compare the amount of solar and wind we need to other ways humans use land. Since a lot of land will be required, it is worth looking at surfaces and activities that can do two jobs at once.

Let's first look at solar. In Table 9.1 we see the U.S. acreage of rooftops, roads, and parking spaces—all places where we could install solar panels. There are details about how to effectively use these land areas for renewable generation, but these are merely meant for comparison. For instance, solar paving of roads gets a lot of attention but it isn't a great idea due to the dirt and abuse of driving cars on top of solar cells. It is better to think about lofting panels over roads, above parking spots, and filling the medians.

Table 9.1 totals 21 million acres. If we use all solar, we would need nearly 15 million acres for panels to produce all our electricity needs. This is more than two-thirds of all our available roofs, roads, and parking spaces. We will need to be putting solar panels wherever we can fit them. There is a camp of environmentalists that believes we'll power the world with distributed solar, but the numbers tell a

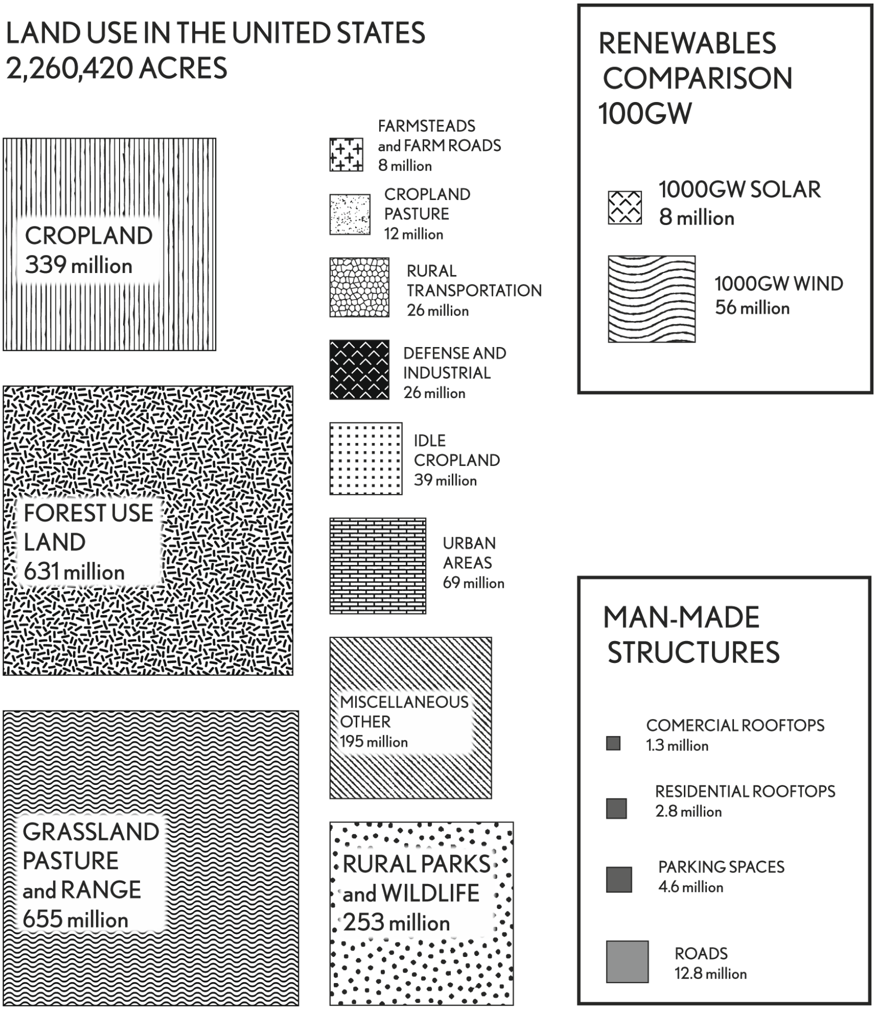

Fig. 9.5 Illustrative areas of the U.S. land use, including reference areas for renewables *Source* by the author; reprinted courtesy of The MIT Press from *Electrify: An Optimist's Playbook for Our Clean Energy Future* by Saul Griffith

Table 9.1 Estimates of land area occupied by our 6 million commercial buildings, 120 million homes, 8.8 million lane-miles of roads, and at least 1 billion(!) parking spaces

Human built thing	Million acres
Commercial rooftops	1.2
Residential rooftops	2.8
Roads	12.8
Parking spaces	4.5

Table 9.2 From United States department of agriculture, economic research service (major land uses)

Human land use	Million acres
Cropland used for crops	339
Idle cropland	39
Cropland pasture	12
Grassland pasture and range	655
Forest-use land	631
Rural transportation	26
Rural parks and wildlife	253
Defense and industrial	126
Farmsteads and farm roads	8
Urban areas	69
Miscellaneous other land	195

simple story: we'll need all of the distributed energy we can harness and we'll need industrial installations of solar and wind as well.

Fortunately, we can also rely on abundant wind resources in the U.S. Let us consider where wind turbines can work for us. Like solar, turbines can do double duty as they harness wind on agricultural and rangelands, among others. Table 9.2 profiles overall land use in the United States, and how it's broken up.

Right away we can see that we have plenty of cropland, where we can also put wind turbines. Idle cropland is ideal for turbines (and perhaps for generating income for farmers). We also have massive amounts of grasslands, pastures, and rangelands where we can place wind turbines. If we set aside land used for urban areas, transportation, defense and industrial, rural parks and wildlife, and forest-use land, we still have about 390 million acres we could use for wind turbines. Some places will be more amenable to wind than others—because of prevailing winds and politics.

There can be no "not in my backyard" with solar and wind energy. Consider that fossil fuels are pervasive and pollute everyone's back yards—in the air, the water, the soil. Over the decades, we have learned to live with a lot of changes in our landscape, from electricity lines and highways to condos and mini-malls. We will also have to live with a lot more solar panels and wind turbines. The trade-offs will be cleaner air everywhere, cheaper energy, and most importantly, we will be saving that land and landscape for future generations. We will have to balance land use with energy needs. But we can see that we are blessed with vast land resources in the U.S., enough that a combination of solar and wind will give us plenty of energy to electrify our economy.

9.8.2 Nuclear

Nuclear energy can work, but 50 years of debating it have passed and we still haven't agreed on the best way to handle proliferation and waste issues. It's not "too cheap to meter," as was once predicted (Wellock 2016); in fact, it is likely more expensive than renewables. The exact costs depend on whom you ask. For instance, the operating costs of a particular plant can be impressively low. On the other hand, many think the costs should include the military and disposal expenses necessary to maintain a safe nuclear fleet, which significantly increasing costs. There are many more examples of such conflicts, leaving the true costs as a matter of considerable debate.

Nuclear has certainly been a reliable source of baseload power. Baseload is the most reliable resource that you are least likely to lose or turn off. Experts now often argue whether baseload is as important as previously thought (Diesendorf 2016). We likely need less baseload power than people think, and perhaps none at all, because of (1) the inherent storage capacity of our electric vehicles; (2) the shiftable thermal loads in our homes and buildings; (3) commercial and industrial opportunities to load-shift and store energy; and (4) the potential capacity of back-up biofuels and various batteries.

The approximately 60 nuclear facilities and 100 reactors in the U.S. already provide roughly 20% (about 100GW) of all our delivered electricity (around 450 GW.) The problem is that nuclear plants take decades to plan and build. In 2016, Watts Bar Unit 2 was connected to the grid after 43 years from the beginning of construction to grid connection[9]. It was the first new reactor in the U.S. since 1996[10]. Only a relative handful of new plants are being planned. Quickly scaling up nuclear power would be difficult.

Another highly under-appreciated problem is that nuclear power plants use river or ocean water to cool down, which ends up heating the water to levels that are deleterious to the fish and plants. 40% of water in the U.S. passes through the cooling cycles of thermoelectric power plants—this ultimately would limit the amount of nuclear power we could deploy with current technology.

We could build nuclear plants faster. We could make them cost less by changing the regulatory environment since the interest rate on the money borrowed to build a nuclear plant can amount to a significant cost addition. We could develop next-generation technologies. We could use mass-production techniques and economies of scale to lower their cost. But that's a lot of what-ifs. It is unlikely that we'll collectively achieve the conviction to build much more nuclear power before the combination of renewables with battery storage proves itself to be more cost-effective and politically favorable.

Nuclear power is so fraught with problems that Japan shut down its plants. So did Germany. China is also slowing down on nuclear technology. This isn't because nuclear doesn't work (it does) but because the socio-political—ecological-economic

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[9] *Watts Bar Nuclear Plant, Wikipedia.* https://en.wikipedia.org/wiki/Watts_Bar_Nuclear_Plant

[10] U.S. Nuclear Industry, U.S. Energy Information Agency. https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php

question marks that surround nuclear make it a long, hard road. And it’s far more costly than solar. The DOE itself has set targets of 5 ¢/kWh for rooftop solar, 4 ¢ for commercial solar, and 3 ¢/kWh for utility-scale solar by 2030 (FOA 2020).

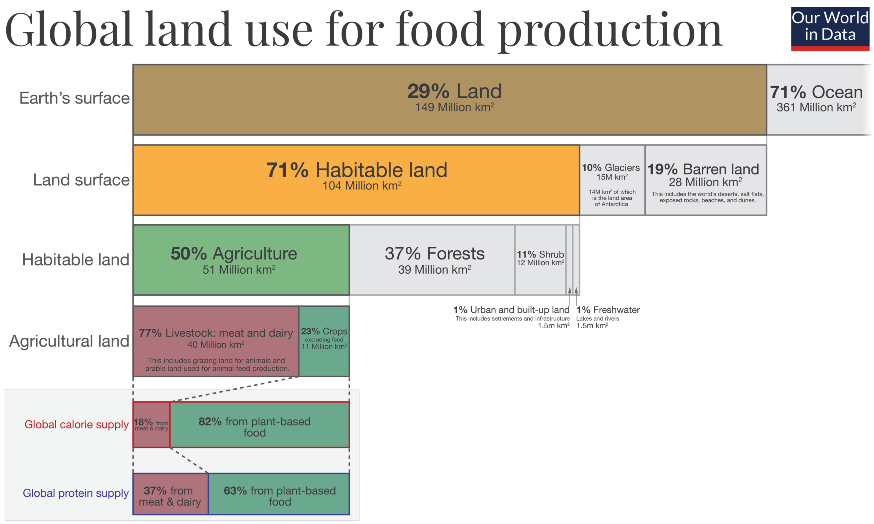
Still, it’s unlikely we’ll eliminate nuclear energy in the U.S. for reasons of national security. Unless we completely disarm, it’s unrealistic to imagine the U.S. pulling out of nuclear power altogether. To address climate change, we’ll likely mildly increase nuclear (fission) power capacity in the U.S., but it probably won’t become the dominant energy source for all the reasons we’ve explained. In other countries with very high population density or a lack of renewable resources, nuclear or imported renewables are the only realistic options.

The world could power itself without nuclear, but for reasons of national security, high population densities, and predictability of supply, pragmatically the world will power some of itself with nuclear. It would be irresponsible to add a lot more nuclear without a lot more investment in improving the technology, waste processing, and security.

There are multiple fusion energy projects and start-ups that have reasonable approaches to the long sought-after goal of fusion energy. To name one, Commonwealth Fusion has a strong and viable pathway to fusion energy, but they themselves admit the challenges of time and cost. If we believe their rigor and claims of 5 ¢/kWh generation and the timeline of their first installed prototype—2032—it is still a bit expensive, and not exactly on the timeline required for limiting the world to only a 1.5 °C increase. Fusion will likely succeed eventually. It may have a dark side however. The wonderful thinker and author, George Dyson (son of physicist Freeman Dyson) poses the question of what humans would do if energy was so cheap we could move mountains on a whim? We probably wouldn’t resist simply moving mountains. Fusion could be a get out of jail free card energy-wise, but would it merely allow us to dominate nature in a way that would destroy it? Think about the consequences of fusion-powered bulldozers. Humans once had the arrogance to propose building the Panama canal with lots of little nuclear explosions…

9.9 Conclusion: Thinking Globally

By electrifying all vehicles, all heating systems, and industry, the U.S. economy could run on around 40% of the energy it does today, at an energy cost of around 4000 W of constant power per person. In a world of 10 billion people, where we each consume 2000–4000 W of constant power, giving everyone a European or North American quality of life via a nearly all-electric energy system, we can estimate our impact. Good solar cells with high coverage could be installed and gather 40 W per square meter of land they occupy. At the high end of our power per capita range, this means each individual would need around 100 square meters of land covered with their pro-rata solar installation. A 100% solar powered, electric world with European and American levels of energy services would thus need 0.5% of the world’s land dedicated to solar cells. For better or worse there are already 65,000,000 km of roads



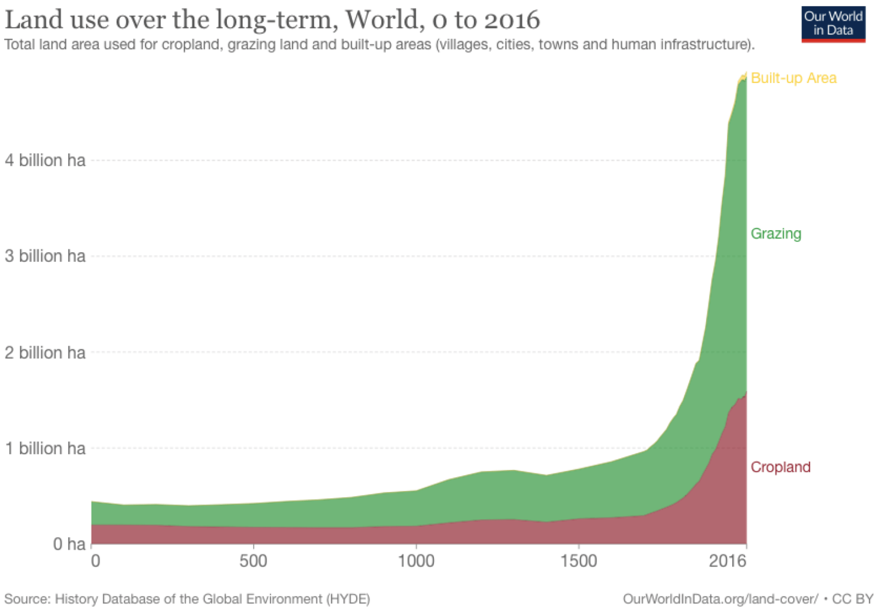
Data source: UN Food and Agriculture Organization (FAO)
OurWorldinData.org – Research and data to make progress against the world's largest problems.

Fig. 9.6 Global land use

in the world. Assuming they average a narrow two lane road of 6 m width, that's about 0.35% of global land area. Assuming a humble 25 m^2 or 250 ft^2 per person of living space, our homes cover about 0.25% of global land area. All settlement and infrastructure of humans are estimated at 1%. If we used our buildings and structures as a large part of our solar energy generation system, it is clear that achieving the amount of solar required to power the world is not unreasonable. Obviously we won't exclusively use solar energy, and dual use of agricultural land with wind and higher energy density nuclear installations will make this goal even more achievable.

Let us put these land use requirements in context with global land use statistics (Fig. 9.6). The land use requirement for all of our energy could be satisfied with less than 2% of the land we grow and graze livestock on. We can look at the history of land use in Fig. 9.7. It is fairly obvious that the land use impact of creating our energy is dwarfed by our agricultural practices. While it is important to be concerned about land-use impact of energy, it is even more important to reign in our voracious appetite for land to feed our collective voracious appetite. The very steep increase in land use for cropland and grazing land through the nineteenth and twentieth centuries cannot continue if we wish to retain any wildland for other species. It should also be obvious that co-locating solar on land that has already been compromised by human intervention is the win–win path.

In 2020, the world consumed a little more than 10 trillion kilograms of fossil fuels. That's around 1300 kg of fossil fuels per person, planet-wide. Are we going to be causing more or less damage to the planet if we use renewables? For the purposes of this thought experiment, let's again take our 4000 W per person energy budget. This is around 125 GJ/year/person, much more than the current 75.7 GJ/year/person,



Land use over the long-term, World, 0 to 2016

Total land area used for cropland, grazing land and built-up areas (villages, cities, towns and human infrastructure).

Source: History Database of the Global Environment (HYDE)

OurWorldInData.org/land-cover/ • CC BY

Fig. 9.7 History of global land use

and taking into account the efficiency of electrification, this means around 5 times as much effective energy use per person, while dramatically improving quality of life. We can make an estimate of the tonnages of things required to sustain that level of energy consumption. Assume a mix of 50% solar and 50% wind energy, and storage of 50% of that energy in Lithium batteries. Assuming a 20 year lifetime for solar, a 25 year lifetime for wind, and 10 year lifetime (or 3700 cycles) for the batteries, the total weight per year per person of things that need to be supplied to meet their energy supply is around 68 kg. Unlike fossil fuels where there is no recycling, we can recycle most of the materials used in these machines. If we develop good recycling for all three of these things, say a rate of 80% which should be achievable, it would mean about 13.5 kg per year per person of stuff. Given that some of the energy will be hydroelectric, geothermal, and nuclear, this number will be even lower.

So, there is quite a good news story here. We could improve everyone's quality of life with an average of 5 times as much energy per person, and achieve it with only around 1% of the material we currently use in supplying our global energy needs. We just need the willpower to wean ourselves off of fossil fuel and develop sustainable strategies for renewable energy.

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