AHR Roundtable

History and Biology in the Anthropocene: Problems of Scale, Problems of Value

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In the age of the Anthropocene, history and biology seem to converge. Ethicist Clive Hamilton maintains that "humans have become a 'natural' planetary force."[1] Historian Dipesh Chakrabarty argues that anthropogenic climate change "spells the collapse of the age-old humanist distinction between natural history and human history."[2] As the divide between the humanities and the sciences melts in the heat of global warming, historians and biologists might reasonably be expected to envision the endangered human figure in similar terms. Accordingly, when asked who is threatened, these disciplines might now answer in chorus, producing a naturalized history, a cultured nature, and an embodied mind. Such a human figure would be recognizable in all corners of the university. Indeed, attempts at unification have been made by both historians and biologists. For instance, Ian Morris and E. O. Wilson have tried to reconcile disciplinary differences and create consilience on the ground, ultimately, of science. As Morris recently put it, "history is a subset of biology is a subset of chemistry is a subset of physics."[3] But I would argue that dynamic engagement between historians and biologists reveals multiple, often incommen-

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[1] Clive Hamilton, *Requiem for a Species: Why We Resist the Truth about Climate Change* (New York, 2010), 9.

[2] Dipesh Chakrabarty, "The Climate of History: Four Theses," *Critical Inquiry* 35, no. 2 (Winter 2009): 197–222, here 201.

[3] Ian Morris, *Why the West Rules—for Now: The Patterns of History, and What They Reveal about the Future* (New York, 2011); E. O. Wilson, *Consilience: The Unity of Knowledge* (New York, 1998). Morris's comment about the relationship of history to the sciences was made at a panel titled "Science and the Human Past: A New Initiative at Harvard University," 127th Annual Meeting of the American Historical Association, January 4, 2013; and again at a panel titled "History on Very Big Scales," 128th Annual Meeting of the American Historical Association, January 5, 2014. Elaborations on this stance can also be found in his most recent book, *The Measure of Civilization: How Social Development Decides the Fate of Nations* (Princeton, N.J., 2013).

surable truths rather than a single answer. History speaks to the issue of the Anthropocene not as a subset of biology but through critical engagement with it.

A brief look at paleobiology, microbiology, and biochemistry shows that historians coming to grips with the Anthropocene cannot rely on our scientific colleagues to define "the endangered human" for us. Instead, biology's diverse branches produce radically different figures of "the human," not all of them endangered by anthropogenic environmental change according to the criteria of societal well-being widely recognized by historians. Rather than simplifying the picture, engaging with biologists complicates the view of who is threatened by the transformation of key earth systems. Although I celebrate the increasingly sophisticated conceptualization of human reality and endorse efforts by historians and biologists to pool their resources in the face of climate crisis, the conclusion I reach is that it is impossible to treat "endangerment" as a simple scientific fact. Instead, endangerment is a question of both scale and value. Only the humanities and social sciences, transformed though they will be through their engagement with science, can fully articulate what we may lose.

"Anthropocene" is admittedly a contested term, but I use it instead of "climate change" or "global warming" because they misleadingly imply that the threat is limited to atmospheric increases in methane and, especially, carbon. A more compelling and inclusive conceptualization of the problem is Johan Rockström and his co-authors' idea of nine "planetary boundaries." As they argue, "Since the industrial revolution (the advent of the Anthropocene), humans are effectively pushing the planet outside the Holocene range of variability for many key Earth Systems processes."[4] These nine important earth systems range from stratospheric ozone to ocean acidification, from changes in land use and freshwater depletion to loss of biodiversity. Human-driven processes of many kinds and their synergistic interactions are transforming the planet and its inhabitants on all levels, from the macroscale of planetary warming to the microscale of industrial neurotoxins' effects on fetal development.

In focusing on the Anthropocene in its full complexity, I am interested in sciences concerned with both macro and micro phenomena. Scale matters, of course, in history as well as biology. It generates controversy in both disciplines because defining the duration and size of a phenomenon determines much about our understanding of it. As all historians know, temporal words such as "big," "deep," and "micro" and spatial concepts like "the Orient" are golden apples of discord.[5] Biologists, too, take sides on the basis of scale. Some take the long view, shrugging off the sixth mass

[4] Johan Rockström et al., "Planetary Boundaries: Exploring the Safe Operating Space for Humanity," *Ecology and Society* 14, no. 2 (2009), http://www.ecologyandsociety.org/vol14/iss2/art32/. Rockström and his colleagues have developed the idea of nine critical planetary boundaries or thresholds that should not be crossed, pertaining to (1) climate change, (2) ocean acidification, (3) stratospheric ozone depletion, (4) the biochemical flow in nitrogen and phosphorus cycles, (5) freshwater over-usage, (6) expanded and intensified land use, (7) biodiversity loss, (8) atmospheric aerosol loading, and (9) chemical pollution. The term "Anthropocene" encompasses all nine dimensions. See also Rockström et al., "A Safe Operating Space for Humanity," *Nature* 461 (September 24, 2009): 472–475.

[5] For a discussion of scale in history, and especially the relationship between modern and premodern history, see Mary C. Stiner, Timothy Earle, Daniel Lord Smail, and Andrew Shryock, "Scale," in Andrew Shryock and Daniel Lord Smail, eds., *Deep History: The Architecture of Past and Present* (Berkeley, Calif., 2011), 242–272. See also David Christian, "Scales," in Marnie Hughes-Warrington, ed., *Palgrave Advances in World Histories* (Basingstoke, 2005), 64–89.

extinction in 540 million years, while others fight for the survival of a single species.[6] The contributions to this roundtable show that history and biology can come together productively on macroscales, as John Brooke and Clark Larsen demonstrate in orchestrating genetics, epigenetics, and cultural change over eons, or on microscales, as with the hormones triggered in Randolph Roth's violent offenders by sociopolitical conditions. In considering the Anthropocene, all scales matter, but it is not clear that they all matter equally to our discipline. We cannot rely on biology to give us the correct answer. Just as Lynn Hunt notes in her essay, "neuroscience does not provide a handy model that historians can simply apply to their research," and the same is true for paleobiology, microbiology, and biochemistry. These three biologies produce visions of "the human" that are incommensurable with one another, as well as with the historian's usual conception of personhood and society. At some registers, "the human" appears not to be threatened at all. The first question, then, is which scales—and surely there are several—are best suited to historians' efforts to understand our global crisis.[7]

The second question has to do with value. Since there is more than one accurate way of describing the human figure, depending in part on scale, we must necessarily make choices about where to focus our attention, and these choices reveal our values. We will have to debate and define the figure of the human that we find most worthy of protecting. Some may resist this responsibility, seeking an objective answer revealed through science, but this is not something that science can provide. The diversity of human figures produced by different ways of knowing should not evoke dismay. Instead, it is a cause for rejoicing, since myriad perspectives in the humanities and sciences give us more conceptual tools. Biologists can help historians broaden our understanding of the human and demonstrate the possibilities and limitations within which humans operate; historians can help biologists understand the varied political and cultural values, economic systems, and multiplicity of ends that leave their imprint on land, air, water, and bodies. We can also help biologists present their findings in the ways most likely to have a desirable impact in an increasingly fragile and precarious world.

My aim here is not to elevate scientific understandings above history's normative understandings of the human, nor to suggest that suturing biology and history is desirable or possible. On the contrary. My purpose is to point with wonder at the incommensurable yet accurate ways in which "the human" emerges in various disciplines, especially in the Anthropocene. As we work at the outer edges of our disciplinary zones, the dialogue should not only illuminate the contributions of various biologies but provide impetus for articulating more clearly history's distinctive modes of understanding. While some sciences such as evolutionary biology also reconstruct the past, "the discipline of history, by contrast," as Reinhart Koselleck

[6] See, for instance, Norman MacLeod, *The Great Extinctions: What Causes Them and How They Shape Life* (Richmond Hill, Ont., 2013).

[7] The urge to restrict useful history to a single, large scale is currently being expressed by David Christian, Cynthia Stokes Brown, and Craig Benjamin, *Big History: Between Nothing and Everything* (New York, 2013); Cynthia Stokes Brown, *Big History: From the Big Bang to the Present*, 2nd ed. (New York, 2012); Jo Guldi and David Armitage, *The History Manifesto* (Cambridge, 2014).

argues, "always performs a political function, albeit a changing one."[8] With the Anthropocene, our political function requires reexamination and rearticulation in conversation with scientists.

For the question of how historians might understand the enormity of our species in the Anthropocene, we can look first to paleobiology. Paleoecologist Curt Stager describes our greenhouse gas emissions as transforming the planet not just for the next several centuries, but into the deep future. We have decisively prevented the next ice age, previously "scheduled" for 50,000 years from today. "Thanks to the longevity of our greenhouse gas pollution," Stager argues, "the next major freeze-up won't arrive until our lingering carbon vapors thin out enough, perhaps 130,000 years from now, and possibly much later."[9] That our actions have such extremely long-term global consequences is staggering, especially given that the Holocene era of human flourishing was only about 12,000 years long. As historian Dipesh Chakrabarty illustrates in his pathbreaking essays, one challenge for historians, perhaps *the* outstanding challenge, is to understand this new aggregate figure of the human: this immense, baleful entity now undermining the earth's life-support systems through a whole array of activities from agriculture to industry, from transportation to communication.[10] Chakrabarty draws on the work of climate scientists, particularly Paul Crutzen and Eugene Stoermer, who in 2000 declared "mankind" a "major geological force," to point to our collective "agency in determining the climate of the planet as a whole, a privilege reserved in the past only for very large-scale geophysical forces."[11] This version of the species pumped up for action on a global scale is, as

[8] Reinhart Koselleck, *The Practice of Conceptual History: Timing, History, Spacing Concepts*, trans. Todd Samuel Presner et al. (Stanford, Calif., 2002), 14.

[9] Curt Stager, *Deep Future: The Next 100,000 Years of Life on Earth* (New York, 2012), 11.

[10] Systems analysis, pioneered in 1972, reminds us that it is not only the burning of fossil fuels that is responsible for climate change, but the whole range of human activities, including agriculture, demographic rates, transport systems, and many other things. See Donella H. Meadows et al., *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* (New York, 1974); Donella H. Meadows, Jørgen Randers, and Dennis L. Meadows, *The Limits to Growth: The 30-Year Update* (White River Junction, Vt., 2004). The attempt to call people's attention to the problem has taken many forms, including an amazingly successful one-man play, *Ten Billion*, written and performed by Stephen Emmott, the head of computational science at Microsoft Research in Cambridge and professor of computational science at Oxford, which essentially consisted of his reading data in sold-out London performances during the summer of 2012. Reviewing the play, Ian Jack writes, "food production already accounts for 30% of greenhouse gases—more than manufacturing or transport; more food needs more land, especially when the food is meat; more fields mean fewer forests, which means even more carbon dioxide in the atmosphere, which means an even less stable climate, which means less reliable agriculture." Jack, "The Implications of Overpopulation Are Terrifying. But Will We Listen to Them?," *The Guardian*, August 3, 2012, http://www.theguardian.com/commentisfree/2012/aug/03/ian-jack-overpopulation-ten-billion. Regrettably, some people continue to believe that laptops, mobile phones, iPads, and other devices that enable electronic communication and thereby supposedly cut down on paper use (as in books) are ecologically sound. On the contrary, tantalum, also known as "coltan," and other rare minerals necessary for these devices are mined in terrible conditions with great harm to the environment. See Michael Nest, *Coltan* (Cambridge, 2011).

[11] Dipesh Chakrabarty, "Postcolonial Studies and the Challenge of Climate Change," *New Literary History* 43, no. 1 (2012): 1–18, here 9. Paul J. Crutzen and Eugene F. Stoermer, "The 'Anthropocene,'" *International Geosphere-Biosphere Programme Newsletter*, no. 41 (May 2000): 17–18, republished in Bill McKibben, ed., *The Global Warming Reader: A Century of Writing about Climate Change* (New York, 2011), 69–74, here 72. Crutzen and Stoermer date the beginning of the Anthropocene to "the latter part of the eighteenth century, although we are aware that alternative proposals can be made (some may even

Chakrabarty urges us to see, what climatologists and paleobiologists are positing in contrast to humanistic and anthropological understandings of the human figure.

Up to this point, the biologist and the historian describe the planetary situation in homologous terms and name the human species as the culprit of climate change. But there the similarities end. For Stager, thinking in terms of the species is easy, and his general argument is that most species, including ours, will survive pretty well, especially if we allow for migration. Looking back on the Eocene era 55 million years ago, which produced temperatures 18–22°F higher than today's, Stager maintains that the Paleocene-Eocene Thermal Maximum (PETM) was not so very terrible: "On a relatively bright note, we also know that many plants and animals, including our own primate ancestors, made it through PETM just fine."[12] This depends, of course, on how you define "just fine." Looking forward into the deep future, Stager explores two models of climate change: a "moderate" one, projecting a rise in atmospheric carbon concentrations to 550–600 parts per million (ppm) with globally averaged temperature increases of 3 to 7°F (2 to 4°C); and an "extreme" one, with carbon reaching 2,000 ppm and temperature rises of "at least 9 to 16°F (5 to 9°C)."[13] Either way, Stager argues, the human species is here to stay. Moreover, he even hints that a new "ethics of carbon pollution" may credit us with having rescued our distant descendants from the "ice age devastation" formerly projected for 50,000 years from now.[14] By extending the timescale of judgment beyond the wildest imaginings of most historians and moral philosophers, Stager suggests that warming the planet might be considered a virtuous act. By his large-scale measure, not only will we be "fine," but we will be *good*.

Chakrabarty, on the other hand, weighs the viability of the concept of "the species" for historians and finds it wanting. This is not because it falsely attributes re-

want to include the entire Holocene)" (71). The ramifications of this periodization have been discussed from a number of angles by historians. See, for instance, Will Steffen, Paul J. Crutzen, and John R. McNeill, "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?," *Ambio: A Journal of the Human Environment* 36, no. 8 (2007): 614–621; Chakrabarty, "The Climate of History." Responses to Chakrabarty include Ian Baucom, "The Human Shore: Postcolonial Studies in an Age of Natural Science," *History of the Present* 2, no. 1 (Spring 2012): 1–23; Simon During, "Empire's Present," *New Literary History* 43, no. 2 (2012): 331–340.

12 Stager, *Deep Future*, 84–85.

13 Ibid., 34, 41. In relying on a projected high of 600 ppm, Stager is following climatologist David Archer's prediction. This figure is considerably higher than NASA scientist James Hansen and environmentalist Bill McKibben's standard for survival of 350 ppm. Our current level is around 400 ppm. Bill McKibben, "Global Warming's Terrifying New Math: Three Simple Numbers That Add Up to Global Catastrophe—and That Make Clear Who the Real Enemy Is," *Rolling Stone*, August 2, 2012, http://www.rollingstone.com/politics/news/global-warmings-terrifying-new-math-20120719. According to the Potsdam Institute for Climate Impact Research and Climate Analytics in their report prepared for the World Bank, "By the time the concentration reaches 550 ppm (corresponding to a warming of about 2.4°C in the 2060s), it is likely that coral reefs in many areas would start to dissolve. The combination of thermally induced bleaching events, ocean acidification, and sea-level rise threatens large fractions of coral reefs even at 1.5°C global warming. The regional extinction of entire coral reef ecosystems, which could occur well before 4°C is reached, would have profound consequences for their dependent species and for the people who depend on them for food, income, tourism, and shoreline protection." Potsdam Institute for Climate Impact Research and Climate Analytics, "4°: Turn Down the Heat—Why a 4°C Warmer World Must be Avoided," Executive Summary, Report for the World Bank, November 2012, 5. See also Mark Lynas, *Six Degrees: Our Future on a Hotter Planet* (Washington, D.C., 2008); David Archer, *The Long Thaw: How Humans Are Changing the Next 100,000 Years of Earth's Climate* (Princeton, N.J., 2010).

14 Stager, *Deep Future*, 11.

sponsibility for altering the climate to human beings. Instead, he argues, "the species" is not something humanist historians can *understand* through self-reflection in Wilhelm Dilthey's sense, where historical consciousness is "a mode of self-knowledge," or in R. G. Collingwood's sense, where historical comprehension rests fundamentally not on reconstructing the past but on reenacting "in our own minds the experience of the past."[15] While "species" may work for paleobiologists comparing, say, the fossil records of Eemian biota from 130,000 years ago with modern organisms, theirs is a labor of reconstruction as opposed to one of self-reflection or mental reenactment. The enormous temporal and spatial scales of paleobiology disallow the tools of intellectual and emotional imagination honed by historians, who in part attempt to penetrate evidence produced by particular minds in the rich context of particular cultures. For most historians, it is only on these smaller scales that political and ethical judgments regarding actions can be made. For one thing, sheer biological survival is not most cultures' ultimate value, their highest ethical or political good. For another, "the species" obfuscates the important distinction between those peoples who cause and benefit from climate change and those who suffer. The concept of species remains for humanist historians such as Chakrabarty a galvanizing flash, important in illuminating the new landscape but unable to provide sustained light.

Chakrabarty's brilliant double move, both toward the sciences and back again to theoretical reflection on our own discipline, is one we can emulate in engaging other biological sciences. Through this dialectic, he demonstrates the problematics of scale and value in distinguishing between history as a description of past events (something we share with many biologists) and history as the formation of self-knowledge. While climatologists and paleobiologists put "species" on the historian's map in unprecedentedly difficult ways because of the macroscales involved, other types of biology, such as microbiology and biochemistry, compound our difficulties by looking at the human on a microscale, raising perplexing issues of human solidarity and continuity. Microbiologists jettison the idea of "the human" as a single species and describe us instead as a coral reef of multiple species, while biochemists examine the industrial toxins suddenly infiltrating our bodies, including our brains, raising questions about the continuity of "the human" in the ways we think and respond to the world.

For historians wishing to understand what it means to be human in the Anthropocene, the minute scale of microbiologists constitutes another distinct challenge, partly because the field is changing so rapidly. In 1969, W. H. Auden wrote "A New Year Greeting" to the "Bacteria, Viruses, Aerobics and Anaerobics" inhabiting his epidermis, inviting these denizens of "Middle-Earth" to

[15] Chakrabarty, "The Climate of History," 220.

settle yourselves in the zone
that suits you best, in the pools
of my pores or the tropical
forests of arm-pit and crotch,
in the deserts of my fore-arms,
or the cool woods of my scalp.

Build colonies: I will supply
adequate warmth and moisture,
the sebum and lipids you need,
on condition you never
do me annoy with your presence,
but behave as good guests should,
not rioting into acne
or athlete's-foot or a boil.

This invitation to microbes to live where they choose as long as they mind their manners accorded with cutting-edge science back then: most microbes were merely "passive riders" on our bodies.[16] Auden was in fact responding to an article in *Scientific American*.[17] Accepting this view, historians ignored the well-behaved "guests" and focused instead on badly behaved parasites, as in William McNeill's pathbreaking *Plagues and Peoples*.[18] Tiny organisms were of no interest to historians unless they turned out to be raging ingrates causing diseases that disrupted human societies.

But microbiology has changed dramatically.[19] Today the relationship between our selves and our microbes is not best described as one between genial host and guests, well-behaved or otherwise. According to recent studies, we are *mostly* bacteria if one counts sheer numbers of cells. With the completion of the Human Microbiome Project in the summer of 2012, the estimated number of bacteria was put at 100 trillion for each healthy human adult.[20] "Going strictly by the numbers," says science writer Valerie Brown, "the vast majority—estimated by many scientists at 90

[16] "Passive riders" comes from microbiologist Bonnie Bassler, as quoted in Gina Kolata, "In Good Health? Thank Your 100 Trillion Bacteria," *New York Times*, June 13, 2012.

[17] Mary J. Marples, "Life on the Human Skin," *Scientific American* 220, no. 1 (January 1969): 108–115. A microbiologist working in New Zealand, Marples published *The Ecology of the Human Skin* (Springfield, Ill., 1965). This pioneering effort of almost a thousand pages applied the term "ecology" to the study of the epidermis for the first time.

[18] William McNeill, *Plagues and Peoples* (New York, 1977). See also Alfred W. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900–1900*, new ed. (Cambridge, 2004); Crosby, *The Columbian Exchange: Biological and Cultural Consequences of 1492* (Westport, Conn., 1973); and in my own field of Japanese history, William Wayne Farris, *Population, Disease, and Land in Early Japan, 645–900* (Cambridge, Mass., 1985); and William Johnston, *The Modern Epidemic: A History of Tuberculosis in Japan* (Cambridge, Mass., 1995).

[19] For a description of earlier research, see Lynn Margulis and Dorion Sagan, *Microcosmos: Four Billion Years of Microbial Evolution* (1986; repr., Berkeley, Calif., 1997).

[20] Just two years earlier, in June 2009, the estimate of unique bacterial genes in each human gut was only about 9 million. Valerie Brown, "Bacteria 'R' Us," *Miller-McCune*, December 2, 2010, http://www.psmag.com/science/bacteria-r-us-23628/. The NIH notes, "In a series of coordinated scientific reports published on June 14, 2012, in *Nature* and several journals in the Public Library of Science (PLoS), some 200 members of the Human Microbiome Project (HMP) Consortium from nearly 80 universities and scientific institutions report on five years of research. HMP has received $153 million since its launch in fiscal year 2007 from the NIH Common Fund, which invests in high-impact, innovative, trans-NIH research. Individual NIH institutes and centers have provided an additional $20 million in co-funding for HMP consortium research." "NIH Human Microbiome Project Defines Normal Bacterial Makeup of the Body," June 13, 2012, http://www.nih.gov/news/health/jun2012/nhgri-13.htm.

percent—of the cells *in what you think of as your body* are actually bacteria, not human cells."[21] Put a different way by the National Institutes of Health, "The human body contains trillions of microorganisms—outnumbering human cells by 10 to 1."[22] Jaw-dropping though this ratio is, it hardly conveys the drama of the new findings. After all, microbial cells are so tiny compared to human cells that they make up only 1 to 3 percent of the body weight of a normal adult.[23] More to the point, the Human Microbiome Project reveals that microbes are neither "passive riders" nor our incidental allies, aiding digestion and the like. Instead, they are inseparably "us," more responsible than "we" are for "our" existence by most calculations on this micro level. In fact, "this plethora of microbes contribute *more genes* responsible for human survival than humans contribute. Where the human genome carries some 22,000 protein-coding genes, researchers estimate that the human microbiome contributes some 8 million unique protein-coding genes or 360 times more bacterial genes than human genes."[24] We would not exist without them. Bacteria participate not only in our physical processes but also in our mental ones (assuming this distinction still holds), producing "some of the same types of neurotransmitters that regulate the function of the brain."[25] For all practical purposes, then, the distinction between "us" and "them," human and microbe, has eroded away on this biological scale.

This human-under-the-microscope looks like a coral reef, "an assemblage of life-forms living together," to Stanford microbiologist David Relman; like a "supra-organism" blending "human and microbial traits" to systems biologist Peter Turnbaugh and his Harvard colleagues; and like a set of "Russian dolls, our lives made possible by the other lives within us," in the metaphor of biologist David George Haskell.[26] A person is not an individual but a congregation. Today, microbiology would inform Auden that he and his microbes are not distinguishable as host and guests. Now everyone pours the wine, joins in the laughter, and scrubs the dishes. Moreover, our microbes, like our friends, can change their behavior. Just as the loutish drunk may surprise the company by digging everyone's car out of the snow, scientists have been surprised to discover the "genetic signatures of disease-causing bacteria lurking in everyone's microbiome. But instead of making people ill, or even infectious, these disease-causing microbes live peacefully among their neighbors."[27] "Bad" bacteria exist with "good" bacteria throughout a healthy body, so that differentiating them is a matter less of ontology than of particular situations.[28]

For historians, microbiology's view of the human poses different challenges from those posed by paleobiology. With paleobiology, the species is an immense, discrete entity: "mankind" in the word of Crutzen and Stoermer. On this macroscale, there

[21] Brown, "Bacteria 'R' Us," my emphasis.

[22] "NIH Human Microbiome Project Defines Normal Bacterial Makeup of the Body."

[23] Brown, "Bacteria 'R' Us."

[24] "NIH Human Microbiome Project Defines Normal Bacterial Makeup of the Body," my emphasis.

[25] Brown, "Bacteria 'R' Us."

[26] David Relman quoted in Kolata, "In Good Health?"; Peter Turnbaugh et al., "The Human Microbiome Project," *Nature* 449 (October 18, 2007): 804–810; David George Haskell, *The Forest Unseen: A Year's Watch in Nature* (New York, 2012), 4.

[27] Kolata, "In Good Health?" Just as "the human" is an aggregate entity, the research done to establish these findings was also communal, coordinated among 200 scientists and 80 institutions; the data generated was so vast that a single mammoth computer would still not suffice.

[28] See, for instance, Nessa Carey, *The Epigenetics Revolution: How Modern Biology Is Rewriting Our Understanding of Genetics, Disease, and Inheritance* (New York, 2012).

are humans and non-humans, with the human species emerging in the Anthropocene as a global agent, the master of the planet over eons of time. But through the lens of microbiology, "the human species" is dramatically less coherent. A microbiological view of "the human" forces historians to grapple with the idea that each "individual" is better understood as a collectivity of species, and "humanity" as an archipelago of multiple, dependent life forms. Self-reflection and mental reenactment as empathetic historical practices, moral and political assessments, analysis of socioeconomic structures, and historical narratives assume a cohesion to "the human" not apparent on this cellular level. Even imaging an archive that would allow us to tell the contingent stories of normal, healthy supra-organisms is difficult. It poses challenges beyond those already encountered by historians of infectious diseases, since epidemics leave traces in state archives and elsewhere because of the havoc they can create. However, before the 1960s, the specificities of healthy microbiomes produced little or no comment. Along with these intriguing conundrums, microbiology's description of "us" as a "supra-organism" or a "coral reef" begs two other major questions: First, how might this perspective inflect our understanding of human solidarity? And second, what light does it shed on who is endangered by climate change?

The question of human solidarity arises because "we" in this microbiological assemblage differ from "one" another more than we had imagined. While about 99.9 percent of our human DNA is shared, our microbial cells may have as little as 50 percent of their genetic profile in common.[29] From the perspective of human solidarity, this finding is disturbing. If 90 percent of my cells are bacterial and half of those have a different DNA sequence than yours, then on a cellular level it is not as clear that we are "the same species," as other branches of biology and most recent histories define us. Biological research on this microscale can distinguish among people in ways that unwittingly resemble discredited racist theories familiar to historians as justifying insidious social and political ideas and institutions. For instance, when five Korean researchers sought to rectify the fact that "studies using deep sequencing analysis have tended to sample Europeans and people from the USA," their findings grouped Koreans, Chinese, and Americans as overlapping, while Japanese people's gut microbiota separated them from Americans and other East Asians.[30] The accompanying chart vividly represents Japan as outlier. (See Figure 1.) Given the longstanding political and military tensions in the Pacific, this chart gives one pause. Here, historians can help biologists. Skilled in providing context and trained to be conscious of the dynamic between evidence and interpretation, historians can usefully raise questions such as whether diet rather than nationality might be a better way of designating the subjects of barcoded pyrosequencing. To say "Japan" rather than "Japanese diets" implies that the nation-state rather than the ingestion of, say, seaweed separates people physiologically. Using political terms for biological groupings may naturalize distinctions between friends and foes. Would it

[29] Turnbaugh et al. point to some of the challenges of answering the question "How similar are the microbiomes between members of a family or members of a community, or across communities in different environments?" "The Human Microbiome Project," 804.

[30] Young-Do Nam, Mi-Ja Jung, Seong Woon Roh, Min-Soo Kim, and Jin-Woo Bae, "Comparative Analysis of Korean Human Gut Microbiota by Barcoded Pyrosequencing," *PLoS ONE* 6, no. 7 (2011): e22109.

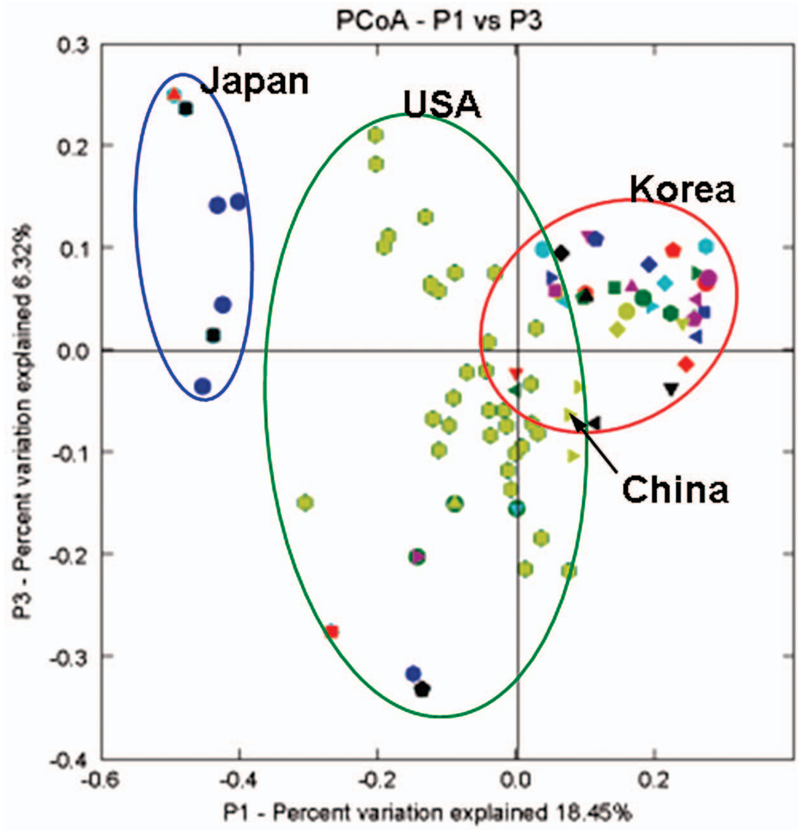

FIGURE 1: "Comparison of Korean gut microbial communities to that of non-Korean people." From Young-Do Nam, Mi-Ja Jung, Seong Woon Roh, Min-Soo Kim, and Jin-Woo Bae, "Comparative Analysis of Korean Human Gut Microbiota by Barcoded Pyrosequencing," *PLoS ONE* 6, no. 7 (2011): e22109, fig. 8.

not be better both for science and for its political and historical consequences if a fuller examination of these categories were undertaken and the findings presented in a way less likely to be misconstrued in a precarious world? I am not suggesting, of course, that these findings are wrong or should be suppressed, but that dialogue between the disciplines will enrich both.

The second problem microbiology poses to historians in the Anthropocene concerns human endangerment, because in some sense "we" on this microscopic scale are not threatened. The reason is that bacteria can respond quickly to environmental changes. Back in 1969, Auden addressed his microbiome, politely hoping that his daily activities such as bathing did not make an "impossible world" for the tiny creatures on his skin. However, by today's understanding, the havoc described by Auden is mild. The slaughter of "ourselves" happens everywhere, including our digestive tracts, where more than half the weight of our feces is composed of extruded microbes. Had Auden understood the true magnitude of microbial destruction, he might have written a dirge.[31] Conversely, a sensibility more attuned to life than death would weigh the astonishing fecundity of parts of our supra-organism against the

[31] Kolata, "In Good Health?"

high death rate, and produce an epithalamium. The microbial part of us reproduces with such rapidity that the number of bacteria, in the right conditions, can double every twenty minutes.[32] These high birthrates are accompanied by a different evolutionary style. Simple prokaryotic cells, without nuclei, mitochondria, or smaller organelles, can conjugate, technically, with any other bacteria, creating an interactive web evolving in many directions at once. Compared with the laborious process of sexual reproduction embraced by eukaryotes, which results in (fairly) linear evolution, prokaryotic cells are like sports cars with the capacity to turn on a dime. Their apparent ability to conjugate with "anyone" means that the very concept of distinct species among bacteria is extremely flexible.

The consequence of this rapid reproduction coupled with differences in evolutionary strategy is that the microbial part of us evolves more rapidly than the non-microbial part of us and can respond more quickly to environmental changes. That a part of us might be capable of coping with more acidic water, wilder weather, and higher temperatures than other parts of us produces a strikingly different version of what might be endangered. Understood in this way, "the body multiple" is not an *entity* to be protected but a *system*, an interactive process of life and death combined.[33] As such, this supra-organism may not be threatened in the Anthropocene in the same way that historians have imagined "the human" to be threatened by famines, rising oceans, and wars for natural resources. On the microscale, with microbiology here and also with biochemistry, as we shall see, "humanity" is *not* the coherent, planet-altering species it is to paleobiologists; nor is it the victim of these alterations in the same aggregate way. Again, the point of underscoring the widely variant visions of "the human" posed by macrobiologists, microbiologists, and biochemists is not to discourage historians from engaging with scientists, but to argue for a careful examination of our own commitments to particular scales and values. If the question is how to use biology to rethink historical issues concerning our past and our possibilities in the Anthropocene, the answers will require considerable theoretical rearticulation of our field.

THE CLAW-LIKE HAND IN KUWABARA SHISEI's photograph *Minamata, 1970* curls in an improbable shape, more reminiscent of photographer Karl Blossfeldt's furled ferns than human digits.[34] (See Figure 2.) This image of a deformity caused by methylmercury from the Chisso chemical plant in Minamata, Japan, is politically potent because it divides the normal from the diseased, the healthy from the ill. Kuwabara's photograph documents the effects of a corporation's criminally inhumane actions and demands redress. If ever there were an instance of "no caption needed," this

[32] The reproductive powers of microbes allow their numbers to recover from incessant attacks by viruses, which invade microbes 10 trillion times a second around the world. Although half of all the bacteria in the oceans are killed by viruses every day, their population remains roughly constant. Carl Zimmer, *A Planet of Viruses* (Chicago, 2012).

[33] "The body multiple" comes from the title of anthropologist Annemarie Mol's fascinating *The Body Multiple: Ontology in Medical Practice* (Durham, N.C., 2002).

[34] Kuwabara Shisei, *Kuwabara shisei shashin zenshu*, vol. 1: *Minamata* (Tokyo, 2004), 118. See Karl Blossfeldt, *Karl Blossfeldt: Fotografie*, ed. Ann Wilde and Jürgen Wilde (Ostfildern-Ruit, 1994).

FIGURE 2: Kuwabara Shisei, *Minamata, 1970*. With the kind permission of Kuwabara Shisei.

image is it, proclaiming a wrong even before the context is made clear.[35] In *Toxic Archipelago*, historian Brett Walker describes how Minamatabyō, this "industrial disease," affected the body and mind of a fisherwoman who lost everything, including her unborn child, to its predations: "In only four years, methylmercury had destroyed enough cells in Sakagami's brain to deprive her of control of herself almost entirely: mercury devours the brains of adults and stops the development of fetal ones."[36] Walker details a horrific scene in which Sakagami, in her confusion, imagines that the oily fish on her hospital dinner plate is her by-then-aborted fetus. When she tries to eat what she thinks is her baby to save it from the pain of methylmercury poisoning,

[35] Robert Hariman and John Louis Lucaites, *No Caption Needed: Iconic Photographs, Public Culture, and Liberal Democracy* (Chicago, 2007).

[36] Brett L. Walker, *Toxic Archipelago: A History of Industrial Disease in Japan* (Seattle, Wash., 2010), 140.

it flops from her chopsticks to the floor. She then chases it, stuffing it into her mouth with her spasmodic hands. Methylmercury also affects non-human organisms. Cats dancing crazily just before they died signaled Minamata's poisoning in its early days. The death of the community's felines led to an explosion of mice that damaged the fishing nets.[37] Unquestionably, methylmercury can destroy life, mental and physical, economic and social, in the womb and out of it, human and otherwise. What Kuwabara's image, Walker's prose, and the death of a hundred convulsing cats clearly show is a situation that should not be.

However, the divide between the body and its non-organic chemical infiltrators is not as clear as the black-and-white photograph or the heart-wrenching stories of Minamata suggest.[38] Biochemists, historians of medicine, and others have come to realize that we must cast aside what Steve Kroll-Smith and Worth Lancaster call "the Enlightenment-inspired idea that bodies and environments are genuinely discrete realities."[39] In many cases, there is not even a threshold between "us" and "outside of us," let alone a stalwart barricade preventing penetration by dangerous substances. The new chemical compounds being pumped out in the millions of tons annually enter our bodies through multiple and little-understood pathways. As historian Nancy Langston explains, "Since World War II the production of synthetic chemicals has increased more than thirtyfold. The modern chemical industry, now a global enterprise of $2 trillion annually, is central to the world economy, generating millions of jobs and consuming vast quantities of energy and raw materials. Each year more than seventy thousand different industrial chemicals annually make their way into our bodies and ecosystems. Americans are saturated with industrial chemicals."[40] In the same vein, historian Michelle Murphy speaks of our "chemical embodiment," stating plainly and powerfully that "in the twenty-first century, humans are chemically transformed beings."[41] "Of the more than 80,000 chemicals in [commercial] use in the U.S.," notes an editorial in *Scientific American*, "the EPA has been able to force health and safety testing for only around 200."[42] Even those of us who

[37] Timothy S. George, *Minamata: Pollution and the Struggle for Democracy in Postwar Japan* (Cambridge, Mass., 2001), 3. See also Ui Jun, *Kōgai no seijigaku: Minamatabyō o otte* (Tokyo, 1968); Frank K. Upham, *Law and Social Change in Postwar Japan* (Cambridge, Mass., 1987).

[38] Such industrial diseases, as Brett Walker carefully reminds us, are "a result of hybrid causation, because of complex and largely unanticipated interrelationships among advanced technologies, idiosyncratic social practices, and naturally occurring agencies." Walker, *Toxic Archipelago*, 139.

[39] Steve Kroll-Smith and Worth Lancaster, "Bodies, Environments, and a New Style of Reasoning," *Annals of the American Academy of Political and Social Science* 584 (November 2002): 203–212, here 204. For approaches considering the ways the nature-culture divide has been definitely overcome, see Dolly Jørgensen, Finn Arne Jørgensen, and Sara B. Pritchard, eds., *New Natures: Joining Environmental History with Science and Technology Studies* (Pittsburgh, 2013).

[40] Nancy Langston, *Toxic Bodies: Hormone Disruptors and the Legacy of DES* (New Haven, Conn., 2010), 17. See also Jody A. Roberts and Nancy Langston, "Toxic Bodies/Toxic Environments: An Interdisciplinary Forum," *Environmental History* 13, no. 4 (October 2008): 629–703, and the related articles in that issue; Sarah A. Vogel, "The Politics of Plastics: The Making and Unmaking of Bisphenol A 'Safety,'" *American Journal of Public Health* 99, supplement 3 (November 2009): S559–S566. Sandra Steingraber, *Having Faith: An Ecologist's Journey to Motherhood* (Cambridge, Mass., 2001); Florence Williams, *Breasts: A Natural and Unnatural History* (New York, 2012); and, Theo Colborn, Dianne Dumanoski, and John Peterson Myers, *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival? A Scientific Detective Story* (New York, 1997).

[41] Michelle Murphy, "Chemical Regimes of Living," *Environmental History* 13, no. 4 (October 2008): 695–703.

[42] The Editors, "Chemical Controls," *Scientific American* 302 (April 2010): 30, http://www.scientificamerican.com/article/chemical-controls/. Fred Magdoff and John Bellamy Foster write, "The

have escaped the horrific deformations visible in Kuwabara's photographs appear biochemically altered when examined by other means of imaging and analysis.

As before, scale is crucial here. Exponentially more chemicals have been introduced throughout the planet more quickly than ever before: greater amounts; vaster coverage; shorter time. This point about scale is important because long before the Industrial Revolution, some people lived in chemically altered environments where such things as lead, mercury, coal, ergot poisoning, and wood smoke harmed human health in circumscribed locales. However, during the "Great Acceleration" after World War II, the new industrial substances infiltrating our bodies became more plentiful, more potent, more complex, and inescapable.[43] By 1986, the substances in Americans included measurable amounts of styrene and ethyl phenol in 100 percent of the population, toluene in 91 percent, polychlorinated biphenyls in 83 percent. "Virtually every person who has lived in the United States since 1951 has been exposed to radiological fallout," the Environmental Protection Agency admits, and "'all organs and tissues of the body have received some radiation exposure.'"[44] All around the world, the toxic load includes phthalates (a toxin derived from plastics) and methylmercury, the substance responsible for Minamata disease. Through a process known as biomagnification, breast milk, once considered the purest food imaginable, actually concentrates dangerous substances such as mercury and the flame retardants known as PBDEs that are suspected culprits in brain damage and developmental disorders.[45]

But, it is not just the large-scale introduction of commercial chemicals that is of concern. Research shows that endocrine disruptors such as the synthetic estrogen used in cattle feed, diethylstilbesterol (the drug DES) prescribed to women to prevent miscarriages, dioxin, PCBs, DDT, and some other pesticides are more dangerous in tiny amounts than in large doses because tiny amounts more closely mimic the body's natural hormone levels. While large amounts of artificial hormones cause the body to resist, small amounts can trigger problems including cancer, especially in reproductive organs. The soup of synthetic chemicals in which we now live puts human masculinity at risk and affects reproduction in wildlife worldwide. Just to take a few of the most startling examples provided by Nancy Langston, "Male alligators exposed to DDT in Florida's Lake Apopka developed penises that were one-half to one-third the typical size, too small to function . . . Prothonotary warblers in Alabama, sea turtles in Georgia, and mink and otters around the Great Lakes all showed reproductive changes. Male porpoises did not have enough testosterone to reproduce, while polar bears on the Arctic island of Svarlbard developed intersex char-

United States continues to have one of the worst records among industrial countries concerning protection of its citizens from toxic chemicals found in products in everyday use—from cosmetics to food containers to denture cream." Magdoff and Foster, *What Every Environmentalist Needs to Know about Capitalism* (New York, 2011), 24. Rockström et al. note that "Of the 80,000 chemicals in commerce, 1,000 are known to be neurotoxic in experiments, 200 are known to be neurotoxic in humans, and five (methyl mercury, arsenic, lead, PCBs, toluene) are known to be toxic to human neurodevelopment"; "Planetary Boundaries," 19.

[43] Steffen, Crutzen, and McNeill, "The Anthropocene," 614.

[44] Kroll-Smith and Lancaster, "Bodies, Environments, and a New Style of Reasoning," 205.

[45] Williams, *Breasts*, chap. 5: "Toxic Assets: The Growing Breast," 87–104. See also Elizabeth Kolbert, "The Nature of Breasts," *OnEarth*, Summer 2012, 54, http://archive.onearth.org/article/anatomy-lessons.

acteristics." Surveys of many British streams discovered that "more than 30 percent of the fish . . . are now intersex."[46] Today, all life on the planet has been fundamentally transformed by the energy-and-resource-intensive activities of the Anthropocene.

What our "chemical embodiment" means is that there is not one group of healthy human beings living without toxic—or potentially toxic but untested—chemicals and another group of unhealthy (and unlucky) human beings living with them. Our chemical environment *is* us, not just in those extreme cases such as Minamata, but everywhere and with everyone. The old idea that there was a barrier between "the body" and "the environment" that could be policed by governments reining in corporations or by individuals making healthy choices no longer pertains as we have come to understand the interpenetrability of bodies and environments. As Langston argues, "Whatever humans do to the natural world finds its way back inside our bodies, with complex and poorly understood consequences. And in turn, what happens inside our bodies makes its way back into the broader world, often with surprising effects."[47] Since the environment is now radically altered, the body is radically altered, too.[48]

Much of the impassioned research tracing the processes responsible for our toxic bodies and our toxic landscapes has been done by historians, so it would be simply wrong to suggest that our discipline has not contributed to the recognition of this chemically altered human figure. Nevertheless, at the theoretical level, we have yet to grasp the challenge to our discipline posed by humanity's unprecedentedly rapid biochemical transformation and by its uneven effects on individuals and communities. History relies, as Chakrabarty and many others argue, on the assumption of a certain continuity of experience that permits us to understand not just what happened, but also how and why it came to pass. This continuity is in part physiological. The figure of "the human" in biochemical terms remains, it has always been assumed, traceable even as it evolves. Daniel Smail puts it this way: "The existence of brain structures and body chemicals means that predispositions and behavioral patterns have a universal biological substrate that simply cannot be ignored . . . Basic social emotions are almost certainly universal. Nonetheless—the point is almost too obvious to bear repeating—they do different things in different historical cultures."[49] But the rapid introduction of hitherto unknown commercial chemicals affecting our bodies—including our brains, as illustrated by Sakagami's hallucinations—threatens this continuity. Historians (and biologists) are now confronted with the problem of how the postwar proliferation of biochemicals might disrupt the traceability of our "universal biological substrate" across space and time. Is it not possible that the Anthropocene's sudden chemical acceleration now separates us physiologically from prewar human beings and from our more vulnerable contemporaries?

[46] Langston, *Toxic Bodies*, 143. For a discussion of scientific concern about the feminization of the human species, see ibid., 135.

[47] Ibid., 136.

[48] This idea of our bodies' permeability resembles nineteenth-century conceptions. Illness then, as Linda Nash shows, was not understood as invading the compromised individual, but instead as arising between individuals and their surroundings. A century ago, doctors could recommend moving to a healthy place; now all habitats are contaminated. Nash, *Inescapable Ecologies: A History of Environment, Disease, and Knowledge* (Berkeley, Calif., 2006).

[49] Daniel Lord Smail, *On Deep History and the Brain* (Berkeley, Calif., 2008), 114.

While both paleobiology and microbiology describe human beings as subject to evolution, biochemistry suggests a revolution.The abrupt emergence of the toxic body is unlike the earlier coevolutionary processes absorbed by historians through the work of Edmund Russell.[50] The only partial analogues are, perhaps, the evolution of the "cognitively fluid" modern mind between 100,000 and 50,000 B.C.E. and the Neolithic agricultural "revolution" beginning some 12,000 to 10,000 years ago, yet those took millennia and were organic rather than inorganic changes.[51] At the usually less-than-toxic levels at which every person today is suffused with industrially manufactured substances, it is hard to imagine that there are not subtle—and perhaps not so subtle—changes in our thought processes and emotional responses. If history involves self-reflection yet the self has been chemically altered, how do we proceed? How would we even be able to measure these effects, given the wide range of human abilities and different individual susceptibilities to chemicals? In asking these questions, we emphasize what we may be losing in terms of historical continuity and human solidarity, and also what neither we nor biochemists yet understand.

On the other hand, if we *are* our chemically altered environment, then who is the "we" endangered by the industrial processes producing climate change? From this perspective, there may be no endangerment. Thoroughly embracing the view that the human organism is part and parcel of its environment would suggest that adaptation to new chemicals is yet another life process, neither good nor bad. In fact, in some corporate circles, the malleability of human physiology is presented as a reason to dismiss climate concerns. In 2009, the U.S. Chamber of Commerce advised the Environmental Protection Agency that should predictions of global transformation be correct, "populations can acclimatize to warmer climates via a range of behavioral, *physiological*, and technological adaptations."[52] The scales of toxicology, both macro and micro, and the values of America's business community appear to mesh. Environmentalist Bill McKibben wryly observes, "As radical goes, demanding that we change our physiology seems right up there."[53] While historians may have difficulty grappling with the figure of the human as seen on biochemistry's scales, we need not accept physiological transformation as necessary or good. Our depiction of human possibilities relies on the arts of persuasion, the articulation of social and political values, and an understanding of the play of power. For historians concerned with biochemistry, as with paleobiology and microbiology, problems of scale and problems of value challenge us to articulate the rationales for our approaches more clearly.

[50] Edmund Russell, *Evolutionary History: Uniting History and Biology to Understand Life on Earth* (Cambridge, 2011); Russell, "Evolutionary History: Prospectus for a New Field," *Environmental History* 8, no. 2 (April 2003): 204–228.

[51] Steven Mithen, *The Prehistory of the Mind: The Cognitive Origins of Art, Religion, and Science* (London, 1996); Mithen, *After the Ice: A Global Human History, 20,000–5000 BC* (Cambridge, Mass., 2004). Not everyone agrees with Mithen's emphasis on the distinctive characteristics of this period between 100,000 and 50,000 B.P. Shryock, Smail, and their co-authors in *Deep History* have suggested that certain hominoid patterns or fractals, particularly kinship systems, can be distinguished as far back as *Homo erectus* and *Homo habilis* some 2.6 million years ago.

[52] U.S. Chamber of Commerce, "Detailed Review of the Health and Welfare Science Evidence," appendix 1 of "Re: Proposed Endangerment and Cause and Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act Docket, ID: EPA-HQ-OAR-2009-0171," June 23, 2009, quoted in McKibben, "Global Warming's Terrifying New Math," 8, my emphasis.

[53] Ibid.

So what can historians interested in the Anthropocene learn from biologists? The answer is lots, much of it destabilizing to our notions of the human and, as Sheila Jasanoff argues, to our central categories of knowledge: community, polity, space, and time.[54] Sociologist Nikolas Rose calls for a "critical friendship" with the life sciences, which he says are now understood as centering around "the vitality of the living body" rather than the old vices of "essentialism, determinism, reductionism, [and] fatalism."[55] Institutions supporting this "critical friendship" include the Rachel Carson Center for Environment and Society in Munich, headed by historians Christof Mauch and Helmuth Trischler, and the interdisciplinary group in Uppsala called the Integrated History and Future of People on Earth (IHOPE), with which John McNeill works. As in all true friendships, achieving balance is crucial. If science trumps the humanities institutionally and as a mode of understanding, it will not be good for any of us. Kenneth Pomeranz, as president of the American Historical Association, rightly criticized President Obama's exclusive elevation of the STEM disciplines (science, technology, engineering, and mathematics) and made an incisive case for history "as a necessary complement."[56] Historians need not suffer from science envy. Instead, we can use the engagement with scientists to articulate the scales and values underpinning historical inquiry as a distinct yet complementary enterprise.

There are two important points I want to make about this "critical friendship," the first having to do with reality and the second with values. First, reality may be described truthfully and cogently in many ways, depending, among other things, on scale. Biology produces manifold descriptions of the human. Each of the biological sciences in my limited sample has defined "us" in a different way, and each poses a different challenge to historians. As Rose puts it, "there is no one biology in this 'biological age.'"[57] For those concerned with the Anthropocene, various biological understandings enrich and broaden our conception of what is at stake. They confirm our embeddedness in the global environment on different scales: in paleobiology, "we" are an increasingly domineering species operating over vast eons of time; in microbiology, "we" are a coral reef of many species spreading out in awkward archipelagos of co-dependent beings; and in biochemistry, "we" are a semi-industrialized product of the last, brief half-century. Each science usefully defamiliarizes "the human" as portrayed by most historians. In defamiliarizing current understandings, biology contributes to history's political project of denaturalizing the status quo, as well as to history's fund of information about climatic conditions, disease patterns, and coevolution. Thinking with biologists reminds us of the biological component of all that we are and do. With them, we go deeper, beyond the old materialism of the economic "base" to a new, and far richer, biological materialism.[58] With them, we trace the limits of our age of abundance and grasp the scale of our exorbitant

[54] Sheila Jasanoff, "A New Climate for Society," *Theory, Culture & Society* 27, no. 2–3 (March/May 2010): 233–253.

[55] Nikolas Rose, "The Human Sciences in a Biological Age," *Theory, Culture & Society* 30, no. 1 (January 2013): 3–34, here 3–4.

[56] Kenneth Pomeranz, "We Need More Than STEM," *Inside Higher Education*, January 28, 2013, https://www.insidehighered.com/views/2013/01/28/essay-criticizing-president-obama-and-other-politicians-who-appear-focus-only.

[57] Rose, "The Human Sciences in a Biological Age," 5.

[58] Julia Adeney Thomas, "Atarashii Busshitsu Shugi" ("The New Materialism"), preface to Thomas,

use of fossil fuels and its implications for life.[59] With them, we learn to think somatically, through the body, like Auden thinking through his bacteria-laden epidermis or Kuwabara thinking with images of malformed hands. Biologists work on many scales, and in engaging with them, historians fruitfully learn to see the human on different scales as well: as species over millennia, as amalgamated with microbes, and as permeated by industrial chemicals. Reality may be described in many true yet incommensurable ways.

But these engagements also remind us of the limits of biological description. When it comes to the Anthropocene, according to much of the work in paleobiology, microbiology, and biochemistry, humans will persist. If our predecessor species survived the horrific heat of the Eocene era, we are likely, Stager says, to survive the heat waves to come. Our microbiome's capacity for rapid evolution suggests that some of us will resist new diseases and adapt to extreme environmental conditions, avoiding the extinction that worries *Scientific American* editor Fred Guterl.[60] Our internal biochemistry's mirroring of environmental toxins will produce deformities and cancers, but likely allow for adequate reproduction rates. And yet this is hardly what most historians and most people mean when they express concern about environmental dangers. It is not mere survival that history teaches us to value, nor description that history teaches us to practice. Ideas about value are another type of knowledge, rooted in cultural genealogies, conversations, and controversies, and true to the extent that they are persuasive rather than provable.

Scientists are not trained to address the questions of value that are central to the humanities. As biologist Stephen Jay Gould argues, "the factual state of the universe, whatever it may be, cannot teach us *how we should live* or *what our lives should mean*—for these ethical questions of value and meaning belong to such different realms of human life as religion, philosophy, and humanistic study. Nature's facts can help us to realize a goal once we have made our ethical decisions on other grounds."[61] When humanists turn to biology for easy answers to questions of value and meaning, they often stumble. For instance, philosopher Thomas Nagel recently insisted on a natural teleology culminating in human consciousness. In response, evolutionary geneticist H. Allen Orr pointed out the greater evolutionary success of fungi, observing that "if nature has goals, it certainly seems to have many and consciousness would appear to be fairly far down on the list." Biology has no special fondness for human consciousness, philosophers, poets, photographers, or (even) historians. Nor a pen-

Kindai no saikochiku: Nihon seiji ideorogii ni okeru shizen no gainen, Japanese translation of *Reconfiguring Modernity: Concepts of Nature in Japanese Political Ideology* (Tokyo, 2008).

[59] There is a dispute between deep historians who have argued that the intensive use of fossil fuels since the eighteenth century is the unremarkable continuation of millennia-old patterns of resource exploitation scaled up, and those who see not only an abrupt quantitative change but a qualitative change as well. For the former position, see Shryock and Smail, *Deep Histories*. For the latter argument, see, for instance, Edmund Burke who refers to modernity as "deeply aberrant." Edmund Burke III, "The Big Story: Human History, Energy Regimes, and the Environment," in Edmund Burke III and Kenneth Pomeranz, eds., *The Environment and World History* (Berkeley, Calif., 2009), 33–53, here 49. For an excellent exposition of the stakes of this debate, see Fredrik Albritton Jonsson, "The Industrial Revolution in the Anthropocene," *Journal of Modern History* 84, no. 3 (September 2012): 679–696.

[60] Fred Guterl, *The Fate of the Species: Why the Human Race May Cause Its Own Extinction and How We Can Stop It* (New York, 2012).

[61] Stephen Jay Gould, "Introduction," in Carl Zimmer, *Evolution: The Triumph of an Idea* (1995; repr., New York, 2002), ix–xiv, here xiii.

chant for peace and decency. Nor any particular desideratum. "If nature is trying to get somewhere," Orr asks, "why does it keep changing its mind about the destination?"[62] What conversations with biologists demonstrate for historians, first and foremost, is that biology is not going to ease our responsibility to understand the human figure on the scales at which we can transform the political and social structures currently ratcheting up global warming. Instead, historians and others in the humanities and social sciences bear the responsibility of describing the values, political institutions, and economic activities that have pertained in past societies so that we can denaturalize present conditions and expand our thinking about possible options. Biologists can help us understand our political predicament, but they cannot provide the political imagination to resolve it.

In the end, climate change is not solely, or even fundamentally, a scientific and technological problem, but a political and social one. Proof of this maxim can be obtained by examining the Little Ice Age, when non-anthropogenic forces plunged the average world temperature down to a frosty 1°C (or 1.8°F). As Geoffrey Parker demonstrates, orchestrating a magnificent array of scientific and historical evidence, famines were dramatically exacerbated by political crises so that an estimated one-third of the global population died off. But in Japan, where political stability was maintained by a combination of the shogunate's sensible if sometimes draconian policies, local customs requiring benevolence by village leaders, and several other factors including sheer good luck, the population grew.[63] Parker shows that understanding the seventeenth-century predicament requires combining science and history, the Little Ice Age *and* the General Crisis, but he also shows that when we scale our story to societal and political registers, we can see why some societies contained their losses while others careened into the jaws of death: "Whereas Europe knew only four years of *peace* during the seventeenth century, and China knew none, Tokugawa Japan knew only four years of war (and none at all after 1638)."[64]

Likewise, in addressing contemporary anthropogenic climate change, political histories are as pertinent as the biological sciences. As American historian Paul Sabin argues, "the energy system reflects political power and social values as much as the latest engineering and science."[65] Historians who operate on the various scales that render us capable of addressing global warming can defamiliarize current re-

[62] H. Allen Orr, "Awaiting a New Darwin," *New York Review of Books*, February 7, 2013, http://www.nybooks.com/articles/archives/2013/feb/07/awaiting-new-darwin/, a review of Thomas Nagel's *Mind and Cosmos: Why the Materialist Neo-Darwinian Conception of Nature Is Almost Certainly False* (Oxford, 2012).

[63] Geoffrey Parker, *The Global Crisis: War, Climate Change and Catastrophe in the Seventeenth Century* (New Haven, Conn., 2013). See especially chap. 16, "Getting it Right: Early Tokugawa Japan," 484–506. Parker's book has generated a lively debate on the interaction of physical factors and human actions. Jan de Vries seems to doubt that climate change as represented by the Little Ice Age can have much impact on human society. De Vries, "The Crisis of the Seventeenth Century: The Little Ice Age and the Mystery of the 'Great Divergence,'" *Journal of Interdisciplinary History* 44, no. 3 (Winter 2014): 369–377. In a different vein, Kenneth Pomeranz wishes that we might learn from mistakes but doubts that "the disasters of the 17th century led to more humane policies in states that 'learned' (either consciously or not) from the crisis, and that a shift from warfare to welfare then made a crucial difference in the West's escape from a Malthusian world." Pomeranz, "Weather, War and Welfare: Persistence and Change in Geoffrey Parker's *Global Crisis*," *Historically Speaking* 14, no. 5 (November 2013): 30–33.

[64] Parker, *The Global Crisis*, 497, emphasis in the original.

[65] Paul Sabin, "'The Ultimate Environmental Dilemma': Making a Place for Historians in the Climate Change and Energy Debates," *Environmental History* 15, no. 1 (2010): 76–93, here 77.

gimes of power and depict compellingly what we are losing in the rapidly heating world. To engage with biologists is crucial; to apprentice the discipline of history to biology is foolhardy and dangerous.[66] We are not junior biologists, nor should we wish to be. In what Rose describes as the epistemic shift in both the human and the biological sciences, whereby "personhood itself is becoming increasingly somatic," biology expands our resources, but history needs to articulate the value of what is endangered and produce the wisdom, grace, and humor, the cultural, political, and social resources available in our records to help address the problem.[67] In the end, what is most endangered is not our fragile bodies but the even frailer edifices of decency, justice, playfulness, and beauty.

In the moment of danger that is the Anthropocene, as the biological figures of the entire species, the supra-organism, and the toxic body flash before us, the most important scales for exploring the human figure remain the ones that come most readily to hand for most historians, the scales in time and space where individuals and communities have some political agency—the scales, in other words, that have long framed our studies. But now there is a difference. In "the century of biology," this figure's environmental embeddedness and somatic being are of equal weight with its conscious actions.[68] Indeed, the two are imbricated with one another. We must be not only "historians of mind," in Collingwood's phrase, where mind and body can be neatly separated, but also historians of eating, sleeping, making love, and much else besides that he dismisses.[69] In so doing, we are politicizing passivity, politicizing the received nature of our environment and bodies without letting go of the need for mindful action.[70] For historians, mindful action occurs in the archives, tracing not only the exponential expansion of human societies since the late eighteenth century, but also the byways taken by those not pursuing the illusion of limitless growth or engaged in the activities that have transformed key earth systems.[71] In revealing multiple viable ways of life, we can offer a somatic politics that counters neoliberalism's naturalization of infinite economic expansion. Biology underscores human malleability, but history provides a forum for deliberating how we might direct this malleability. Engaging with biology reveals a multiplicity of human figures and delimits the possible answers to humanistic questions of value, but it cannot decide

[66] Jerry A. Jacobs makes the argument for maintaining disciplinary protocols in *In Defense of Disciplines: Interdisciplinarity and Specialization in the Research University* (Chicago, 2013). I make the argument for expanding the purview of our discipline in "Not Yet Far Enough," *American Historical Review* 117, no. 3 (June 2012): 794–803.

[67] Rose, "The Human Sciences in a Biological Age," 7.

[68] Geneticists Craig Venter and Daniel Cohen have declared that "the 21st century is the century of biology." Venter and Cohen, "The Century of Biology," *New Perspectives Quarterly* 21, no. 4 (2004): 73–77, here 73.

[69] R. G. Collingwood, *The Idea of History* (Oxford, 1946), 216.

[70] See my argument in "From Modernity with Freedom to Sustainability with Decency: Politicizing Passivity," in Kimberly Coulter and Christof Mauch, eds., *The Future of Environmental History: Needs and Opportunities* (Munich, 2011), 53–57.

[71] I am indebted to the work of Fredrik Albritton Jonsson on European cornucopianism: Albritton Jonsson, "The Origins of Cornucopianism: A Preliminary Genealogy," *Critical Historical Studies* 1, no. 1 (Spring 2014): 151–168.

them. History can help here; this is where we perform Koselleck's "political function."

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