READING 3

David Christian, "World History in Context" *Journal of World History* 14, no. 4 (December 2003): 437–52.

Abstract: World history can provide a context for regional and national histories, but what is the context for world history itself? If world history is about the history of human beings, asking this question means asking about the place of human beings within modern knowledge. While most traditional cosmologies put humans at the center of the picture, the temporal and spatial scales of modern science are so vast that humans can seem to vanish entirely. Yet if we order the contents of our universe by complexity rather than by size or longevity, things look different. This paper explores arguments suggesting that human societies and their evolution may be among the most complex objects available for scientific study. Such conclusions hint at the significance of world history beyond the history profession and also suggest the extraordinary difficulty of the challenges world historians face.

History is all about context. As Joyce Appleby, Lynn Hunt, and Margaret Jacob have written, "what historians do best is to make connections with the past in order to illuminate the problems of the present and the potential of the future." [1] That is why historians so often complain about fields such as international relations that focus almost exclusively on current events and issues. However, historians haven't always been so good at putting their own discipline in context. Oddly enough, this applies even to world history. One of the virtues of world history is that it can help us see more specialized historical scholarship in its global context. But what is the context of world history itself? This is a question that has not been sufficiently explored by world historians. [2] Yet it should be, for all the reasons that historians **[End Page 437]** understand so well when we criticize other disciplines for neglecting context.

One of the aims of world history is to see the history of human beings as a single, coherent story, rather than as a collection of the particular stories of different communities. It is as much concerned with nonliterate communities (whether they lived in the Palaeolithic era or today) as with the literate communities that generated the written documents on which most historical research has been based. World history tries to describe the historical trajectory that is shared by all humans, simply because they are humans. Understood in this sense, world history is about a particular species of animal, a species that is both strange and immensely influential on this earth. So, to ask about the context of world history is to ask about the place of our particular type of animal, *Homo sapiens*, in the larger scheme of things. This question encourages us to see world history as a natural bridge between the history discipline and other disciplines that study changes in time, from biology to cosmology.

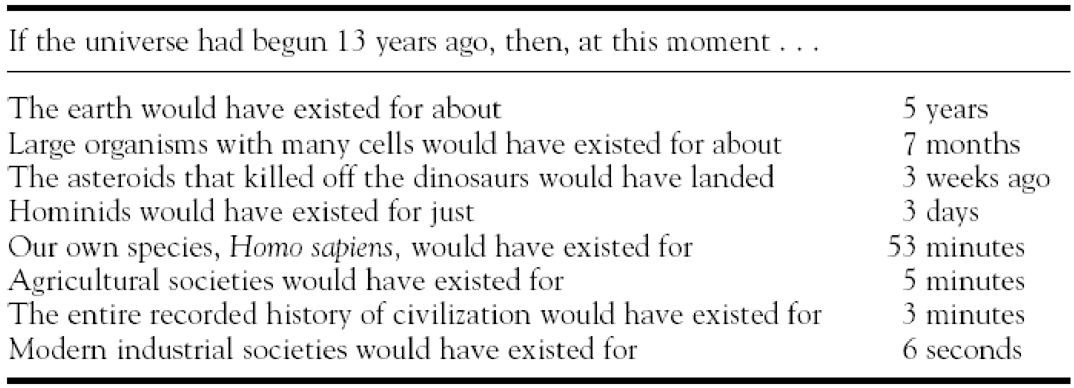
Modern Cosmologies Often Seem To Decenter Human Beings

In most creation stories, humans are reasonably close to the center of the universe. In the Ptolemaic system, which dominated cosmological thinking in medieval Europe, the earth was at the center of a series of transparent spheres. Attached to these spheres were the planets, the sun, and the stars, all revolving around Earth, whose main function, it seemed, was to provide a home for human beings. However, the evolution of modern cosmologies has decentered the earth and the human beings who inhabit it. In the sixteenth century, Copernicus offered some powerful new arguments to suggest that Earth revolves around the sun. In the seventeenth century, Giordano Bruno argued that every star could be a separate sun, perhaps with planets of its own. By the eighteenth century, it was common to suppose that the universe might be infinite in both time and space. The universe of contemporary cosmology has limits in both time and space, but it is still huge—so huge that it can make our species and the planet we inhabit seem utterly insignificant.

Some calculations may illustrate how modern cosmologies can appear to diminish our species. In a Boeing 747 cruising at about 900 kilometers (550 miles) per hour, it would take us almost twenty years to reach the sun, which is about 150 million kilometers (about 95 million **[End Page 438]** miles) away. To reach our closest neighbor, Proxima Centauri, it would take the same jumbo jet more than five million years. [3] This is the distance between next-door neighbors in a galactic city of one hundred billion stars. To get a feeling for the size of our galaxy, the Milky Way, we need to move at the speed of light. It takes light only eight minutes to reach the earth from the sun, but it would take a beam of light about four years and four months to reach Proxima Centauri. The same light beam would have to travel for another thirty thousand years, or ten thousand times the distance to Proxima Centauri, before it reaches the center of our galaxy. Yet our galaxy is just one of perhaps one hundred billion galaxies that inhabit a universe many billion light years in diameter. [4]

The temporal scales of modern cosmology are as daunting as its spatial scales. Ever since Edwin Hubble showed, in the 1920s, that the universe was expanding, it has seemed possible, in principle, to determine the age of the universe by estimating its rate of expansion. The details of this calculation are tricky, but today cosmologists are converging on an age of about 13 billion years. [5] We cannot really grasp such colossal periods of time, but, with an imaginative effort, we can perhaps get some sense of their relationship to human history. The chronology in Table 1 collapses the timescales of modern cosmology by a factor of one billion. It reduces thirteen billion years to thirteen years, and picks out some of the dates within these scales that are most significant for our own species.

Table 1. The chronology of the universe compressed into 13 years



If the universe had begun 13 years ago, then, at this moment . . .	
The earth would have existed for about	5 years
Large organisms with many cells would have existed for about	7 months
The asteroids that killed off the dinosaurs would have landed	3 weeks ago
Hominids would have existed for just	3 days
Our own species, *Homo sapiens,* would have existed for	53 minutes
Agricultural societies would have existed for	5 minutes
The entire recorded history of civilization would have existed for	3 minutes
Modern industrial societies would have existed for	6 seconds

All in all, it may seem that our earth and our species have no significance at all within modern cosmology. Indeed, this may be one reason **[End Page 439]** why so many people feel that modern science has little to tell them about what it *means* to be human. This is very different from the cosmologies of most premodern communities, which had plenty to say about humans and their significance within the wider scheme of things.

Maps Of Complexity Tell A Different Story

However, the spatial and temporal maps of modern science are not the only maps that modern science offers us. Other maps tell different stories. One of the most interesting is the "map of complexity." Instead of comparing different objects by their size and age, this compares them by their degree of "complexity" or "order." Neither of these terms is easy to pin down, and there exists no agreement on their precise definition, but a commonsense definition will take us a long way. The physicist Eric Chaisson defines order (or complexity) as "a state of intricacy, complication, variety, or involvement, as in the interconnected parts of a structure—a quality of having many interacting, different components." [6] Despite the difficulties we face in pinning down such **[End Page 440]** notions, there are some powerful lines of argument about order and complexity that have interesting implications for our own species. The rest of this article will explore some of these arguments and try to tease out their significance for world history as a field of scholarship.

There is a close link between the notions of order and complexity and the laws of thermodynamics. The second law of thermodynamics is one of the fundamental principles of modern physics. While the first law of thermodynamics asserts that energy is never lost, the second law asserts that in any closed system (such as the universe as a whole) the amount of energy that is available to do work tends to diminish. “Entropy” is the term used to measure the amount of energy that can no longer do work, so we can restate the second law to say that in a closed system entropy tends to increase. The law can be appreciated more easily if it is put slightly differently. All work depends on the existence of an energy differential, a difference in energy levels. A charged battery can do work because of the “potential difference,” or voltage, between the positive charge at one terminal and the negative charge at the other terminal. However, as it does work (for example by running a light), the difference between the two terminals diminishes until, eventually, there is no difference at all. At that point, no more work can be done. The battery has reached a state of equilibrium. The energy it supplied has not vanished (the heat and light generated by the light bulb will have diffused into its surroundings), but the energy no longer exists in forms that can do work. The second law implies that the universe as a whole is tending toward such a state of equilibrium, a state of perfect disorder, in which all energy differentials have been evened out, and no more work can be done. This end state used to be called “the heat death of the universe.”

The Austrian physicist Ludwig Boltzmann (1844–1906) argued that the second law can best be understood as a consequence of statistical processes. Any system can exist in many possible states. However, the vast majority of these states are disordered or chaotic. So, if a system starts out with some structure (a tidy room is a familiar example), random change ensures that over time it will become more and more disordered, simply because most possible states are disordered. Boltzmann gave the example of a room in which all the gas molecules were squashed into one corner. This is a possible but colossally unlikely situation. If the system is left to evolve on its own, it will tend toward one of the many less ordered states, in which the gas is spread evenly throughout the room. What this seems to imply is that as the universe moves toward a state of thermodynamic equilibrium, it will become less and less ordered. Order is rare. As Stuart Kauffman puts it, “The **[End Page 441]** consequence of the second law is that in equilibrium systems, order—the most unlikely of the arrangements—tends to disappear… It follows that the maintenance of order requires that some form of work be done on the system. In the absence of work, order disappears.” [7] Understood in this way, the second law seems to mean that complex structures, from stars to starfish, can exist only if they can tap into a constant flow of new energy. [8] Simple structures are easier to create and maintain because they do not require such energy flows, so it is no surprise that much of the universe appears to be quite simple.

Nevertheless, over the thirteen billion years since the universe was created, complex entities have appeared and many scientists (particularly biologists) have argued that the upper threshold of complexity has slowly risen.[9] What seems to happen is that where large energy flows are available, they can sometimes bind independent entities into new and more complex structures, just as gravitational energy forced simple atoms of hydrogen to fuse into more complex elements within the first stars. Given the difficulties of pinning down the notion of complexity, it should be no surprise to find that measuring levels of complexity is tricky. Nevertheless, Eric Chaisson has proposed an interesting approach to the problem.[10] Chaisson argues that the more complex an object is, the denser the energy flows that pass through it. If it takes energy to create and sustain complex, far-from-equilibrium systems, it makes sense to suppose that the more complex a phenomenon is, the more energy it will need to sustain its high level of complexity. Consequently, if you measure how much energy flows through a given mass in a given amount of time, and you do this calculation for a number of different entities that inhabit our universe, you should be able to come up with a rough ranking by degrees of complexity. **[End Page 442]**

The results of Chaisson's calculations are summarized in Table 2. They suggest that there is a clear hierarchy of complexity, and that within that hierarchy living organisms seem to be much more complex than stars. As Martin Rees has written, "a star is simpler than an insect."[11] Yet a star also lives much longer. Intuitively, this makes sense. Juggling concentrated flows of energy is a difficult and precarious trick, so perhaps we should not be surprised that those things that do this do not live long. They are fragile and they are rare. Complexity, dense energy flows, fragility, and rarity seem to go together. So, if we rank the contents of the universe not by size or age but by complexity, we find that living organisms loom larger than they do within the modern maps of space and time. Indeed, they provide a benchmark against which we can measure this universe's creativity, its capacity to generate complex things.

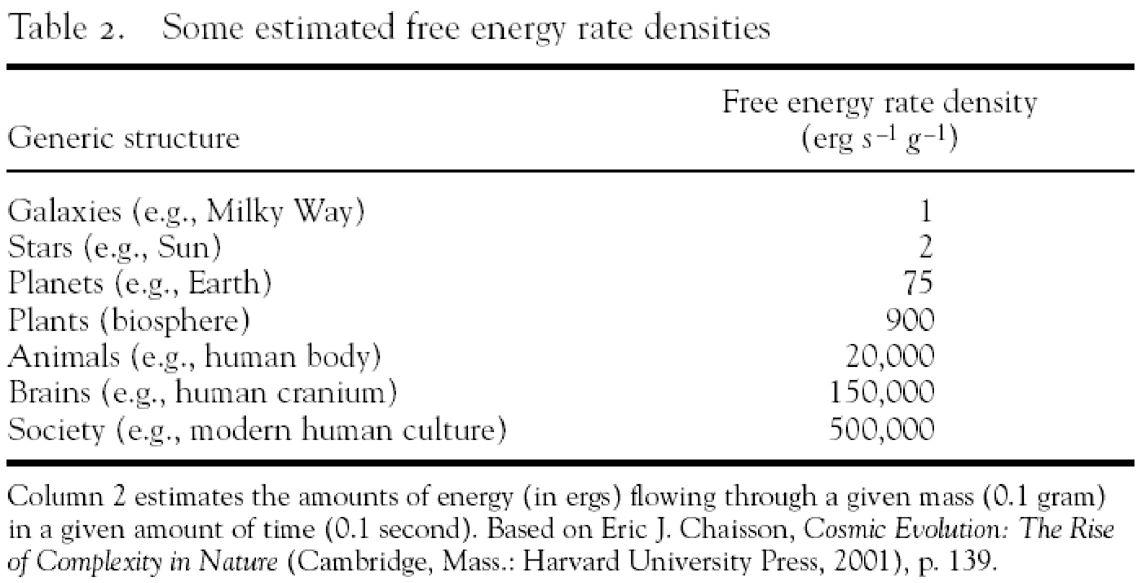


Table 2. Some estimated free energy rate densities

Generic structure	Free energy rate density ($\mathrm{erg}\ s^{-1}\ g^{-1}$)
Galaxies (e.g., Milky Way)	1
Stars (e.g., Sun)	2
Planets (e.g., Earth)	75
Plants (biosphere)	900
Animals (e.g., human body)	20,000
Brains (e.g., human cranium)	150,000
Society (e.g., modern human culture)	500,000

Column 2 estimates the amounts of energy (in ergs) flowing through a given mass (0.1 gram) in a given amount of time (0.1 second). Based on Eric J. Chaisson, *Cosmic Evolution: The Rise of Complexity in Nature* (Cambridge, Mass.: Harvard University Press, 2001), p. 139.

One expression of the complexity of living organisms is their superior ability to adapt to their environments. Over time, living organisms change in ways that allow them to tap the energy surrounding them with more efficiency. Adaptation enables living organisms to find more and more ways of extracting the energy flows they need to maintain their complex structures. These structures, in turn, provide the machinery that makes adaptation possible. So, in an elegant feedback **[End Page 443]** mechanism, complex structures make it possible to tap the large energy flows needed to sustain complexity. As Darwin showed, living organisms adapt mainly through a blind process of trial and error. Of the millions of individuals that are born, many will die before reproducing. Those that happen to have characteristics that improve their chances of survival are more likely to flourish and have heirs, so the characteristics that helped them survive will be passed on to their descendants. Over time, Darwin argued, these mechanisms have given rise to all the species alive on earth today. In the spirit of Eric Chaisson's arguments about complexity, we can argue that natural selection allows species to adjust to changes in their environment, so they can extract the energy flows needed to maintain their complex structures. As we now know, the structures that allow adaptation through natural selection are indeed complex. They are encoded in (at least in this corner of the universe) DNA molecules that, even in the simplest organisms, contain many billions of atoms ordered with exquisite precision.

Why Is Human History So Complex? A New Level of Complexity

How do human beings fit into these maps of complexity? Chaisson's calculations suggest that they are central. In the course of two or three hundred thousand years they have learned to tap larger flows of energy than any other organisms on earth, and this suggests that in some sense they are more complex. What explains this difference between humans and other living organisms?

There has been endless debate about what it is that makes us human, but when viewed on a very large scale, it seems to me that there is a strikingly simple answer. Natural selection has been the dominant mechanism of adaptation in the biological world, but it is not the only mechanism. There is a second adaptive mechanism that has evolved among some living organisms: learning. Many animal species, from earthworms to elephants, have brains, which enable individual members of the species to adapt to their environment during a single lifetime. Individuals learn where to hunt for prey, where to hide, how to avoid predators. During their lifetime, they get better at the job of staying alive. However, when they die, all (or almost all) the skills acquired during a lifetime of adaptation are lost. A mother chimpanzee can encourage her children to do some things and discourage them from doing other things, but she has little ability to pass on complex or abstract information, just as human parents would be very limited if **[End Page 444]** they had to teach their children purely through mime. In the animal world, learned information cannot be passed on with the precision and detail of genetic information. So each individual starts the learning process more or less from scratch. Individual learning of this kind affects individuals, but has a limited impact on the evolution of entire species. This is why in the nonhuman world learning has been a much less important adaptive mechanism than natural selection.

However, things would be very different if older chimpanzees could pass on their knowledge as precisely as their genes. This would mean that each individual could inherit the results of numerous experiments conducted over many generations and pooled in a common cultural bank. Furthermore, the store of knowledge in the species's cultural banks would increase over time as more and more ideas were stored. Here we would have a species that learned collectively rather than individually. The entire species would now be able to cooperate in the task of learning. And that, more or less, is the sort of species we are. What distinguishes humans from all other organisms is the evolution of symbolic language—the capacity to exchange information with great precision. Symbolic language marks a revolution in the capacity to communicate information. As Marvin Harris puts it, "Human language is unique in possessing semantic universality, or the capacity to produce unlimited numbers of novel messages without loss of informational efficiency. In contrast to gibbon calls, for example, human language has unrestricted powers of productivity." [12]

Symbolic language made available to humans a third adaptive mechanism, which we can call "collective learning," to contrast it with the individual learning of all earlier learning species. Because of collective learning, members of our species can inherit knowledge as well as genes. The difference between humans and their near relatives, such as the chimps, is much more than a difference in brain size. Human brains are indeed larger than those of chimps, but chimps are very clever animals, all the same. The real difference is apparent only when you compare the individual brain of a chimp with the collective brain of millions of humans. That is what really accounts for the astonishing differences in the history of these two closely related species. Humans no longer function just as individuals. Almost every object or idea we use today represents the stored knowledge of previous generations. **[End Page 445]** Language links individual humans into the large, evolving structures that we refer to as "societies," just as individual cells once combined into the larger and more complex structures of multicellular organisms.

The results are transformative. Instead of adapting at the glacial pace of genetic change, our species can adapt at the much more rapid pace of cultural change. Whereas genes can be passed on only to one's immediate offspring, knowledge can be passed on to anyone who is willing to listen, so knowledge can spread much more rapidly than genes. Furthermore, because cultural adaptation is cumulative, the pace of adaptive change accelerates. The more humans there are, and the more they interact, the larger the store of accumulated knowledge about how to adapt to the environment. Here we have an entirely new mechanism of adaptation, one so powerful that it eventually swamped the underlying genetic mechanisms that made it possible in the first place. As a result of this new, nongenetic, mechanism of adaptation, humans have acquired over time an astonishing ecological power, based on an accelerating capacity for finding new ways of extracting energy and resources from their surroundings. As McMichael puts it:

> …the advent of cumulative culture is an unprecedented occurrence in nature. It acts like compound interest, allowing successive generations to start progressively further along the road of cultural and technological development. By traveling that road, the human species has, in general, become increasingly distanced from its ecological roots. The transmission of knowledge, ideas and technique between generations has given humans an extra, and completely unprecedented, capacity for surviving in unfamiliar environments and for creating new environments that meet immediate needs and wants. [13]

It is collective learning that distinguishes human history from natural history. Collective learning ensures that human history, unlike that of other species, is a process of accumulation and acceleration, and it is this process of cumulative and accelerating adaptation to the natural environment that is traced in world history. All in all, collective learning is so powerful an adaptive mechanism that there is a case for arguing that it plays an analogous role in human history to that of natural selection in the histories of other organisms. If so, perhaps collective learning should be a central theme in any attempt to weave a coherent account of world history. **[End Page 446]**

The acceleration in human ecological power made possible by this new adaptive mechanism is already apparent in the archaeological record of the Palaeolithic era. Before modern humans appeared, technological change occurred, but it was extremely slow. The Acheulian stone tools characteristic of *Homo erectus* changed little in a million years. However, as an important recent survey of African prehistory shows, there are hints that the pace of technological change began to accelerate from about 250,000 years ago.[14] That acceleration may date the first appearance of modern humans equipped with symbolic language and capable of collective learning. For perhaps one hundred thousand years or more, modern humans were confined to the African continent, but innovation is apparent in new types of stone tools, in the appearance of new technologies such as the use of shellfish, and in evidence of long-distances exchanges. Then, from about one hundred thousand years ago the evidence becomes clearer. Further innovations allowed groups of humans to migrate to new environments, both within Africa (where humans began to settle regions of desert and equatorial forests) and beyond. Whereas our closest relatives, chimpanzees, remained in the ecological niche within which they had evolved, humans learned how to exploit an increasing variety of niches throughout the world, despite the fact that each niche required new skills and new knowledge. By one hundred thousand years ago, some modern humans had migrated out of Africa. This in itself was not particularly significant. The environments they found in the southern parts of the Eurasian landmass were not that different from those of their African homelands, and many other primate and mammal species (including some of our own hominid ancestors) had made similar migrations. The first migration that provides clear evidence of a significant increase in human adaptive skills is probably the migration to Sahul (the ice-age continent of Australia and Papua New Guinea). This took place between sixty thousand and forty thousand years ago. No earlier mammal had made this migration; the sea crossing alone suggests remarkable seafaring skills, while learning to exploit the unfamiliar plants and animals of Sahul must have demanded great ecological suppleness. The second migration that demonstrates our species's growing ecological virtuosity is the migration into ice-age Siberia that began perhaps forty thousand years ago. To survive in these cold lands, **[End Page 447]** our ancestors had to learn new survival skills, including improved control of fire and new forms of tailoring, as well as new hunting skills. These migrations continued with the entry of humans into the Americas (perhaps thirteen thousand years ago), by which time humans could be found in most parts of the world. The process was completed by the migrations that populated the many islands of the Pacific in recent millennia.[15]

Then, a mere ten thousand years ago, humans began to exploit their environments intensively as well as extensively.[16] They found ways of extracting more energy from a given area, by diverting more of the energy flowing through the biosphere to their own uses. They did this by manipulating their surroundings so as to reduce the production of species they did not need ("weeds" and "pests" are the generic terms we use today for such organisms) and to increase the production of species they found useful. Eventually, such manipulation began to modify the genetic structure of the most favored species in the Neolithic version of genetic engineering that we call "domestication." In these ways, agriculture increased human control over local energy flows, allowing our ancestors to live in larger and more densely settled communities. Humans began not just to adapt to new niches, but to create new niches in the villages and cities of the Neolithic era. As populations grew, interactions between individuals and communities multiplied, and the process of collective learning itself intensified. In recent centuries, the rate of change has accelerated once more. The web of human interactions has thickened and stretched out until in the last five hundred years it has linked all societies on earth. Within the global networks of the modern era, information can be exchanged faster and more efficiently than before and processes of collective learning can generate entirely new levels of synergy.[17]

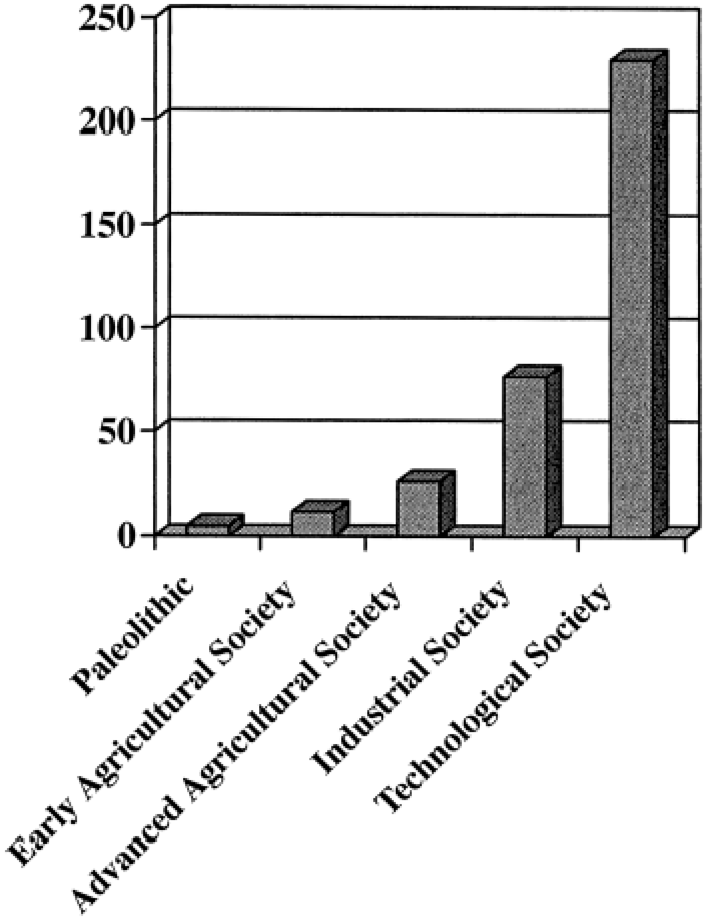
As humans settled in denser communities they became more interdependent **[End Page 448]** and their social networks became more complex. State formation, from about five thousand years ago, is one of the most striking measures of the increasing complexity of human societies, as individuals and communities found themselves incorporated into larger and more complex social machines than ever before. Given Chaisson's notion of the link between energy use and complexity, we should expect to find that these changes correlate with increasing use of energy, and they do. Population growth is itself a powerful measure of the increasing ecological power of our species, as it implies the capacity to control more and more of the energy available to the biosphere. Just to keep their bodies functioning, humans need about three thousand calories of energy a day. Ten thousand years ago, there may have been six million humans, each consuming at least this much energy, but not much more. Today, there are one thousand times as many humans (more than six billion), so we can be sure that our species now consumes at least one thousand times as much energy as we did ten thousand years ago. At the same time, as Table 3 and Chart 1 suggest, each modern human consumes on average about fifty times as much energy as our ancestors did ten thousand years ago. If these figures are correct, they suggest that, as a species, we now consume about fifty thousand times as much energy as our ancestors once did (Chart 2). **[End Page 449]** They demonstrate a control over energy that no other species can match. The equivalent graph for chimpanzees (or, for that matter, for any other nonhuman animals) would show no significant change in either total or per capita energy consumption over the last one hundred thousand years or more.

Table 3. Average daily per capita energy consumption in different historical eras (units of energy = 1,000 calories per day)

	Food (incl. animal feed)	Home and commerce	Industry and agriculture	Transportation	Total per capita	World population (millions)	Total energy consumption
Technological society (now)	10	66	91	63	230	6,000	1,380,000
Industrial society (100 B.P.)	7	32	24	14	77	1,600	123,200
Advanced agricultural society (1000 B.P.)	6	12	7	1	26	250	6,500
Early agricultural society (5000 B.P.)	4	4	4		12	50	600
Hunting society (10,000 B.P.)	3	2			5	6	30
Protohumans	2				2		

Based on I. G. Simmons, *Changing the Face of the Earth: Culture, Environment, History*, 2nd ed. (Oxford: Blackwell, 1996), p. 27.

Chart 1: Energy Consumption per Capita in different eras
(measured in 1,000 calories per person per day)
Data from Table 3, column 5, top 5 rows



The accelerating ecological power of humans shows up in many other ways as well. One of the most powerful measures of human ecological power is summarized in Table 4. The table gives the dates by which 25%, then 50%, then 75% of several different types of ecological impact had been reached. For example, the date 1950 in the population row and the 50% column implies that half of all human population growth occurred after that date (within the lifetime of many **[End Page 450] [Begin Page 452]** people alive today). The table shows clearly how human impacts on the environment have accelerated in the last two centuries. [18]

Chart 2: Total energy use of all humans in different eras

Total Human Energy Use Over 100,000 Ys
(1,000 Cals. Per day)
Data from Table 3, column 7

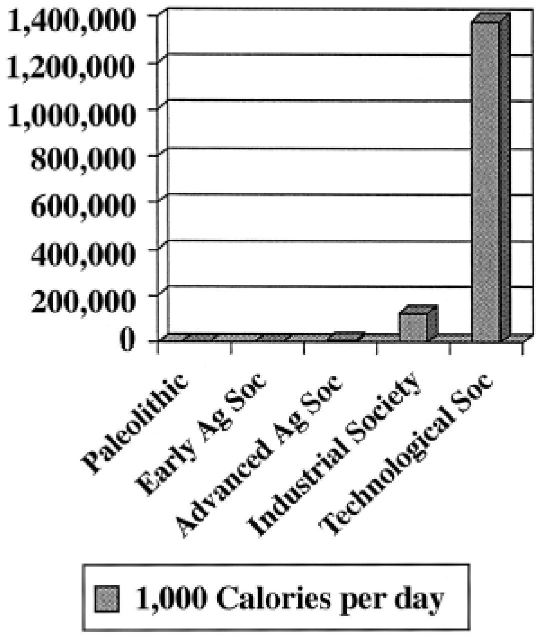


Table 4. Quartiles of human-induced environmental change from 10,000 B.C. to mid-1980s

Form of transformation	Dates of quartiles		
	25%	50%	75%
Deforested area	1700	1850	1915
Terrestrial vertebrate diversity	1790	1880	1910
Water withdrawals	1925	1955	1975
Population size	1850	1950	1970
Carbon releases	1815	1920	1960
Sulfur releases	1940	1960	1970
Phosphorus releases	1955	1975	1980
Nitrogen releases	1970	1975	1980
Lead releases	1920	1950	1965
Carbon tetrachloride production	1950	1960	1970

From R. W. Kates, B. L. Turner, and W. About Clark, "The Great Transformation," in B. L. Turner, W. About Clark, R. W. Kates, J. F. Richards, J. T. Mathews, W. B. Meyer, eds., *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years* (Cambridge: Cambridge University Press, 1990), p. 7.

On What Scales Are Humans Significant?

Clearly, human history marks something new in the history of our planet. How significant is the appearance of our species? Can we measure our impact? In rough and ready ways we can, and these measures offer an important way of appreciating the wider significance of the history of our species.

Most of the energy that supports life on earth arrives in the form of sunlight. Living organisms need a lot of energy. So it is no accident that we live near a very hot object, the sun. At its center, our sun is at least ten million degrees, the temperature needed for fusion reactions to begin. Yet the average temperature of the universe is about three degrees above absolute zero. Like campers around a campfire, we live in a cold universe, near a source of heat, and it is this colossal energy differential that sustains complexity on earth. The torrent of energy that pours from the sun into the icy surroundings of space provides most of the energy needed to support our biosphere. Through photosynthesis, plants tap some of the energy of sunlight and store it in the cells of their own bodies. Other organisms capture their share of that energy by eating plants, or other animals that have eaten plants. In this way, like water flowing through irrigation canals, the energy of sunlight is distributed throughout the food chains of the biosphere. However, in a powerful demonstration of the effects of the second law of thermodynamics, much of that energy (often more than 90%) is dissipated at each step in its flow through the food chain, so that less and less is available to do the hard work of nourishing complex organisms. This is why food chains normally have fewer than four or five links, and why we normally find fewer organisms in the later links of the food chain. This is why wolves are less numerous than sheep.

However, the new adaptive mechanism of collective learning has helped our own species to overcome many of the ecological constraints that check the growth of all other species on earth. By diverting to **[End Page 452]** their own use the energy channeled through many different food webs, humans have multiplied despite their position at the top of many food chains. The Russian physicist and demographer Sergey Kapitza has argued that "the human species now numbers at least one hundred thousand times more members than any other mammal of similar size and with a similar position in the food chain." [19] Today, humans may be controlling anything from 25% to 40% of the energy derived from photosynthesis and distributed through land-based food chains. [20] In addition, in the last two centuries, humans have learned to tap the huge stores of energy buried millions of years ago in the fossilized bodies of ancient plants and microorganisms, and available today in coal, oil, and natural gas. These statistics indicate the astonishing ecological power acquired by our species in the course of its history.

Increasing human control over the energy and resources of the biosphere has measurable consequences for the entire biosphere. If one organism hogs so much of the energy needed to sustain the biosphere, less will be available for other organisms. So it is no surprise that as humans have flourished other species have withered. (The exceptions are those plants and animals that have been invited or have barged their way onto the human ecological team, from cows and corn to rats and rabbits. [21]) This means that rates of extinction provide a rough measure of our impact on the biosphere. Currently, about 1,096 of 4,629 mammal species (24%) are thought to be "threatened"; 1,107 of 9,627 bird species (11%); 253 of 6,900 reptile species (4%); 124 of 4,522 amphibian species (3%); 734 of 25,000 fish species (3%); 25,971 of 270,000 higher plant species (10%). [22] The pace of extinctions appears to be accelerating, so we can expect a lot more in the near future.

But even current rates of extinction are shockingly high. Some paleontologists have concluded that they are approaching the rates of **[End Page 453]** extinction during the five or six most drastic extinction episodes of the last billion years. [23] If so, human activity, and particularly human activity in recent centuries, will be visible on the scale of a billion years. If paleontologists visit this planet in one billion years' time and try to decipher the history of the planet using the tools of contemporary human paleontology, they will identify a major extinction event at about the period we live in, and they will notice it was quite sudden. They will find it comparable to five or six other events of similar magnitude that occurred during the previous billion years, and they may be tempted to think of it as the equivalent of a meteoritic impact, such as the impact or impacts that appear to have driven most species of dinosaurs to extinction about sixty-seven million years ago. Our impact will certainly be detectable on a scale of six hundred million years (that of multicelled organisms) and probably on the scale of planetary history (4.5 billion years). This means that the history of our species is a matter of planetary significance. To say this of a group of species, such as the dinosaurs, might not be so remarkable; to say it of a single species really is odd.

There are tentative arguments suggesting that the level of complexity represented by human societies may be rare, not just on a planetary scale, but even on a galactic scale. Simple life forms, analogous, perhaps, to earthly bacteria, may turn out to be very common in the universe. At present, we simply don't know if this is true. However, as we come to understand how common planetary systems are, how rugged simple organisms can be, and how fast life evolved on our own earth, it appears more and more likely that there are millions, if not billions, of life-friendly planets just within our own galaxy, and life may have evolved on many of them. [24]

However, intelligent, networked species like ourselves that can adapt through collective learning may be much rarer, because collective learning depends on the existence of more complex structures than those that power the other familiar adaptive mechanisms of natural selection and individual learning. On this planet, the vehicle for collective learning is symbolic language. Symbolic language depends on the evolution of unusually large and powerful brains (relative to body **[End Page 454]** size). Yet evolving large brains has been a slow and difficult process on this planet. On earth it has taken more than three billion years, or almost a quarter of the entire lifetime of the universe, to evolve very large brains, and it is not hard to see why. Even simple brains are extraordinarily complex, and require much nutrition and energy to support them. Each human brain contains perhaps a hundred billion nerve cells, as many cells as there are stars in an average galaxy. These connect with each other (on average, each neuron may be connected to one hundred other neurons) to form networks that may contain sixty thousand miles of linkages. Such a structure can compute in parallel. That means that though each computation may be slower than that of a modern computer, the total number of computations being carried out in a particular moment is much, much greater. While a fast modern computer may be able to complete one billion computations a second, even the brain of a fly at rest can handle at least one hundred times as many. [25] Surely, evolving a biological computer as powerful as this must have been a good Darwinian move. Yet if brains are so obviously adaptive, why have so few species evolved really large brains in comparison with their body size? Part of the trouble is that brains are so complex that they need a lot of energy. The human brain uses almost 20% of the energy needed to support a human body, but accounts for only 2% of body weight. [26] Bearing large-headed infants is also difficult and dangerous, particularly for a bipedal species, as bipedalism requires narrow rather than wide hips. How fragile large-brained organisms may be is suggested by hints in the genetic record that our own species has come very close to extinction. As late as one hundred thousand years ago, well after our species had appeared but before it had begun to have a discernible impact on the biosphere, human populations may have fallen to as few as ten thousand adults. This means that our species came as close to extinction as mountain gorillas today. [27] If our ancestors had perished, there is no guarantee that natural selection would have created another such creature on our earth. This is a powerful reminder of the haphazardness of evolutionary processes and of the fragility of complex entities.

The evolution of large-brained creatures such as ourselves was one of the less likely outcomes of evolutionary processes, because brains **[End Page 455]** represent a risky evolutionary gamble. The Emperor Hirohito did research on a type of sea squirt that has a tiny brain early in its life. It uses its brain to make an epic voyage in search of a rock to perch on. Once it has arrived, it sits still and sieves plankton, so it no longer needs such an ecologically expensive organ. With remorseless logic, it eats its own brain.[28] As Stephen Hawking puts it, "Bacteria do very well without intelligence and will survive us if our so-called intelligence causes us to wipe ourselves out in a nuclear war."[29] Brains illustrate perfectly why complex things seem to be both fragile and rare.

If the evolution of creatures capable of collective learning was unlikely within the frame of planetary history, it may also have been unlikely on much larger scales.[30] After all, if such creatures were common, they should have evolved somewhere else, perhaps even within our own galaxy with its hundred billion stars, and some of them should have appeared millions, even billions, of years ago. In principle, they could have appeared within a few billion years of the first supernovae, which began scattering through the universe the chemical elements that are the raw material of chemical and biochemical evolution. If species capable of collective learning had evolved several billion years ago, some of them would surely have achieved the level of technological sophistication of modern humans and passed well beyond it. Eventually, some would surely have created technologies vastly superior to those we have created on Earth, including superior technologies of transportation and communication. By this logic, there ought to be millions of planets in our galaxy inhabited by intelligent, networked creatures such as ourselves. Yet we have not a shred of evidence that this is so. As the physicist Fermi once asked, "Where are they?"[31] In the twentieth century, humans managed to leave their own planet for the first time. If we do not destroy ourselves, it is likely that in the next few centuries we will travel to nearby planets and in a millennium or **[End Page 456]** two we will travel to nearby star systems. (If it takes us a hundred thousand instead of just a thousand years, the argument still stands.) As we travel beyond our solar system, we will broadcast our presence in signals that will travel far ahead of us. At present, we have no reason to believe that intelligent beings anywhere else in the galaxy have achieved as much. The absence of clear evidence for extraterrestrials capable of collective learning suggests that human beings may be unique on a galactic, even perhaps a cosmological scale. So, while the evidence is growing that *life* in general may be common in the universe, *intelligent, networked* life-forms such as ourselves that can adapt through collective learning may be extraordinarily rare. Perhaps entities as complex as modern human societies arise close to the limit of our universe's capacity to generate complexity.

These arguments may or may not work. All they are intended to suggest is that the modern creation story does not necessarily deprive human history of meaning and significance. From some points of view, the modern creation story suggests that humans are remarkable, unusual, and profoundly important. In the distant future, many billions of years after we are gone, the universe will run down. It will continue to expand, but, under the harsh rule of the second law of thermodynamics, the energy differentials that support life today will diminish. Stars will flicker out and die, the universe will get colder and colder as it ages, and it will gradually lose the ability to fashion complex objects such as a fly or a polar bear or a human being. In retrospect, it will seem that we were among the most complex entities created by the universe in the youthful period when it had the energy to conjure up such miracles. On the modern map of complexity, humans are as central as they were within most traditional cosmologies.

For world historians, this conclusion is full of significance. It suggests, first, that world history—the discipline that studies the history of human beings—has significance across many scales and well beyond the conventional boundaries of the history discipline. It also suggests why compiling world history is so extraordinarily difficult. Constructing a coherent history of a species as complex as ours is a challenge as daunting as any in modern science. It will require many different types of historical research and scholarship, on many different scales. Fortunately, the field is already characterized by a remarkable openness to different approaches, styles, and methodologies. Yet the argument of this essay suggests that writing world history well may also require a serious attempt to see the history of our species in the context of other stories, including those of our planet and our universe. That will mean **[End Page 457]** making more use than we normally do of the insights of specialists in neighboring fields, from biology to cosmology.[32] Just as the early pictures of earth taken from the Apollo missions made it easier to appreciate our own planet, so the view from outside world history may make it easier to understand the uniqueness and importance of world history, to identify the themes and problems that set it apart from neighboring disciplines, and to appreciate its underlying cohesion.

Footnotes

* This essay is based, in part, on a paper given to the Royal Holland Society of Sciences and Humanities at their 250th anniversary symposium in Haarlem in May 2002: "Maps of Time: Human History and Terrestrial History" in *Symposium ter Gelegenheid van het 250-jarig Jubileum*, Koninklijke Hollandsche Maatschappij der Wetenschappen: Haarlem, 2002. My thanks to the Society for permission to reproduce some passages from that paper.

1. Joyce Appleby, Lynn Hunt, and Margaret Jacob, *Telling the Truth about History* (New York and London: W. W. Norton, 1995), p. 9.

2. Exceptions include William H. McNeill, whose article "History and the Scientific Worldview," in *History and Theory*, 37, no. 1 (1998): 1–13, places world history within the context of other historical sciences, including biology and cosmology; and Fred Spier, *The Structure of Big History: From the Big Bang until Today* (Amsterdam: Amsterdam University Press, 1996). There have also been some remarkable books by scientists that set human history in its cosmological context; they include Nigel Calder's remarkable chronology *Timescale: An Atlas of the Fourth Dimension* (London: Chatto and Windus, 1983) and John Gribbin, *Genesis: The Origins of Man and the Universe* (New York: Delta, 1981), both of which are now slightly dated. Fred Spier has compiled a fuller bibliography of such works by historians and scientists. It can be found at <http://www.i2o.uva.nl/inhoud/engels/bighistorybooks.htm>.

3. I owe these analogies to the late David Allen of the Anglo-Australian Observatory in Sydney and Coonabarabran, Australia.

4. The universe may be even larger than it appears. The theory of inflation asserts that, for a fraction of a second, just after the moment of creation, the universe expanded faster than the speed of light. If so, the real universe may be much bigger than the portion we can observe: "If the entirety of an inflationary universe were the surface of the earth, the observable part would be smaller than a proton." Timothy Ferris, *The Whole Shebang: A State-of-the-Universe(s) Report* (New York: Simon & Schuster, 1998), p. 78. Dmitri Linde's notion of "chaotic inflation" even considers the possibility that there may have been multiple Big Bangs, each producing a new universe. See Ferris, *The Whole Shebang*, pp. 258–264. In a similar vein, Lee Smolin has argued that we may live "in a continually growing community of 'universes,' each one of which is born from an explosion following the collapse of a star to a black hole." Lee Smolin, *The Life of the Cosmos* (London: Phoenix, 1998), p. 110.

5. Evidence from the Wilkinson Microwave Anisotropy Probe (WMAP) released by NASA in February 2003 implies that the Big Bang occurred about 13.7 billion years ago. This is the most precise date calculated so far for the origin of our Universe.

6. Eric J. Chaisson, *Cosmic Evolution: The Rise of Complexity in Nature* (Cambridge, Mass.: Harvard University Press, 2001), p. 13. As Chaisson points out, there are many subtle problems in defining complexity or order. One, which can be disposed of immediately, is that there are two very different types of order. One is the order of a system that is stable because it is close to equilibrium, and requires no more energy to maintain its present condition, such as the position of a billiard ball that has dropped into a pocket. This essay is concerned with a different type of

order, which arises in conditions very far from equilibrium, and requires a constant throughput of energy, such as a whirlpool. (The distinction is described well in Stuart Kauffman, *At Home in the Universe: The Search for Laws of Complexity* [Harmondsworth: Viking, 1995],p. 20.)

7. Kauffman, *At Home in the Universe*, pp. 9–10.
8. Ilya Prigogine and Isabelle Stengers have described complex structures as "dissipative" systems because of the huge amounts of energy that they use and then dissipate into their surroundings. They also argue that the appearance of ordered structures is quite likely under conditions far from equilibrium. "In far-from-equilibrium conditions we may have transformation from disorder… into order." Ilya Prigogine and Isabelle Stengers, *Order out of Chaos: Man's New Dialogue with Nature* (Glasgow: William Collins, 1984), p. 12.
9. Chaisson, *Cosmic Evolution*, pp. 11–14, discusses other scientists who have held this view; for a robust statement of this position from a biologist's point of view, see J. Maynard Smith and E. Szathmáry, *The Origins of Life: From the Birth of Life to the Origins of Language* (Oxford: Oxford University Press, 1999). The late Stephen Jay Gould was a dissenter on this, as on so many other biological orthodoxies. See *Full House: The Spread of Excellence from Plato to Darwin* (New York: Harmony Books, 1996).
10. Chaisson, *Cosmic Evolution*, p. 139.
11. Martin Rees, "Exploring Our Universe and Others," *Scientific American* 281, no. 6 (Dec. 1999): 46.
12. Marvin Harris, *Culture, People, Nature: An Introduction to General Anthropology*, 5th ed. (New York: Harper & Row, 1988), p. 155; Harris's chapter on language is a good introduction to the linguistic revolution that lies at the origins of human history.
13. A. J. McMichael, *Planetary Overload: Global Environmental Change and the Health of the Human Species* (Cambridge: Cambridge Univeristy Press, 1993), p. 34.
14. Sally McBrearty and Alison S. Brooks, "The Revolution That Wasn't: A New Interpretation of the Origin of Modern Human Behaviour," *Journal of Human Evolution* 39 (2000): 453–563.
15. Useful surveys of these migrations include Clive Gamble, *Timewalkers* (Harmondsworth: Penguin, 1995); John Mulvaney and Johan Kamminga, *Prehistory of Australia* (Sydney: Allen and Unwin, 1999); Brian M. Fagan, *The Journey from Eden: The Peopling of Our World* (London: Thames and Hudson, 1990); Ben Finney, "The Other One-Third of the Globe," *Journal of World History* 5, no. 2 (1994): 273–297; J. R. McNeill, "Of Rats and Men: A

Synoptic Environmental History of the Island Pacific," *Journal of World History* 5, no. 2 (1994): 299–349.

16. B. D. Smith, *The Emergence of Agriculture* (New York: Scientific American Library, 1995), is a good summary of the transition to agriculture.
17. The growth of networks or "webs" of exchange and communication is the central theme of J. R. McNeill and William H. McNeill, *The Human Web: A Bird's-Eye View of World History* (New York: W. W. Norton, 2003).
18. This acceleration has been explored superbly in John McNeill's recent environmental history of the twentieth century, *Something New under the Sun: An Environmental History of the Twentieth-Century World* (New York and London: W. W. Norton, 2000); see also Andrew Goudie, *The Human Impact on the Natural Environment*, 5th ed. (Oxford: Blackwell, 2000).
19. Cited in Johan Goudsblom, "Introductory Overview: The Expanding Anthroposphere," in B. DeVries and J. Goudsblom, eds., *Mappae Mundi: Humans and Their Habitats in a Long-Term Socio-Ecological Perspective* (Amsterdam: Amsterdam University Press, 2002), pp. 21–46, from p. 26.
20. I. G. Simmons, *Changing the Face of the Earth: Culture, Environment, History*, 2nd ed. (Oxford: Blackwell, 1996), p. 361, adapted from J. M. Diamond, "Human Use of World Resources," *Nature* 328 (1987): 479–480.
21. Alfred W. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900– 1900* (Cambridge: Cambridge University Press, 1986), is all about the impact of this sort of teamwork in the last 500 years.
22. *World Resources 2000–2001: People and Ecosystems: The Fraying Web of Life* (Washington, D.C.: World Resources Institute, 2000), pp. 246, 248.
23. See, for example, Richard Leakey and Roger Lewin, *The Sixth Extinction: Patterns of Life and the Future of Humankind* (New York: Doubleday, 1995).
24. Paul Davies, *The Fifth Miracle: The Search for the Origin of Life* (Harmondsworth: Penguin, 1999) (particularly chapter 10, "A Bio-Friendly Universe?"), and Malcolm Walter, *The Search for Life on Mars* (Sydney: Allen and Unwin, 1999), discuss how common life may be in the universe.
25. Roger Lewin, *Complexity: Life on the Edge of Chaos* (London: Phoenix, 1993), p. 163.
26. Roger Lewin, *Human Evolution*, 4th ed. (Oxford: Blackwell, 1999), p. 190.
27. C. Stringer and R. McKie, *African Exodus* (London: Cape, 1996), p. 150.
28. Daniel C. Dennett, *Consciousness Explained* (London: Penguin, 1993), p. 177. In an aside that all academics will recognize, Dennett adds that this transition is "rather like getting tenure."

29. Stephen Hawking, *The Universe in a Nutshell* (New York: Bantam, 2001), p. 171.

30. There is a good discussion in Nikos Prantzos, *Our Cosmic Future: Humanity's Fate in the Universe* (Cambridge: Cambridge University Press, 2000), pp. 162–169.

31. Nikos Prantzos, *Our Cosmic Future*, pp. 162–169. As Prantzos points out (p. 164), Fermi's question had already been raised by Fontenelle in the eighteenth century. For a more optimistic assessment of the chances of finding intelligent life, see Armand Delsemme, *Our Cosmic Origins: From the Big Bang to the Emergence of Life and Intelligence* (Cambridge: Cambridge University Press, 1998), pp. 236–244.

32. Recent works by Jared Diamond have shown how fruitful and provocative the insights of a biologist can be for world historians. See, in particular, *Guns, Germs, and Steel*, (New York: W. W. Norton, 1997).