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Prosperity in the Very Long Run

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Homo augens

Prosperity, *n*.: "A successful, flourishing, or thriving condition, especially in financial respects; good fortune." So says dictionary.com, but there are plenty of other definitions out there, focusing on everything from spiritual wellbeing to health and happiness.[1] Yet all of them, in the end, seem to rest on the same thing: energy. Humans have bodies, and whether your idea of prosperity is financial, spiritual, or felicitous, you will have none of it unless you consume roughly 2,000 kilocalories of energy every day. People with access to more than 2,000 kilocalories per day can turn their surplus energy into whatever makes them feel prosperous, whether that is stocks and bonds, churches, hospitals, or even a conference at the Hoover Institution. However we think about prosperity, it all comes down to energy.

My aim in this paper is to show that the pursuit of prosperity is part of human nature. I try to do by tracing its history back to humanity's very beginnings, and even beyond. Certainly for the last 45,000 years, probably for the last 300,000 years, and quite possibly for the last 1.8 million years, humans have been finding ways to accumulate greater flows of energy. The process has been uneven and interrupted, but in the long run it has been so relentless that rather than calling ourselves *Homo sapiens*, "Wise Man," we should probably speak of *Homo augens*, "Growth Man";[2] and in important ways, this story is just the latest chapter in a much longer story that is, very literally, as old as time itself.

My paper has five sections in addition to these few words of introduction. In the first, "Stylized History," I quickly describe what I take to be the dominant view of long-run prosperity in the academy. Then, in "Universal Growth," I situate the study of prosperity within the larger study of the evolution of energy flows. The next section, "Measuring Long-Term Prosperity," asks how we can measure energy rate density—the essence of prosperity—across tens of thousands of years. In "Prosperity in the Very Long Run," I draw on recent work in archaeology, ancient history, evolutionary anthropology to provide some empirical detail for our relentless rise of prosperity. I focus on the earlier periods, partly because these are generally poorly known outside specialist circles, but also for the practical reason that these are what I have been working on in the last few months. Finally, in my conclusion, I summarize why I think this very long-run history of prosperity might be useful for those interested in prosperity's future.

Stylized history

Several decades talking to colleagues in anthropology, archaeology, history, and the social sciences more broadly have led me to conclude that not many academics sympathize with my view that we are *Homo augens*. At one time, plenty of scholars did feel that tracing across tens of thousands of years how much energy we capture from our environments, how efficiently we use it, and how we find new ways to apply it were legitimate and even necessary tasks. There are, to be sure, a few exceptions, but for several generations now, social scientists have favored simpler theories of prosperity, which they often dignify with the label Malthusian.[3]

The most popular theory seems to be that there was very little prosperity until 1800 CE, then a lot more, beginning in western Europe and since 1945 spreading to the rest of the world. The Nobel Prize-winning economist Robert Lucas, for instance, tells us that "In the front hall of my apartment in Chicago is a painting of an agricultural scene," showing "a farmer plowing his field behind an ox." No records say how much the farmer earned; but, says Lucas, "we don't need them," because "up to 1800 or maybe 1750, no society had experienced sustained growth." This means that "traditional agricultural societies are very like one another, all over the world," and therefore that "incomes in all societies were stagnated at around [the equivalent of] $400 to $800 per year." The economic historian Greg Clark is even more sweeping. "The average person in the world in 1800 was no better off than the average person of 100,000 BC," he tells us, even making up a graph (Figure 1) to illustrate his point. Even more extreme versions, however, come from my own fields of ancient history an archaeology. Moses Finley, the most influential ancient historian of the twentieth century, condemned efforts to measure Greek and Roman economic growth a "schoolboy version of Adam Smith"; the anthropologist David Graeber and archaeologist David Wengrow, in their bestselling book *The Dawn of Everything*, dismiss any attempt to measure ancient incomes or inequality (and my own in particular) as "a bit silly."[4]

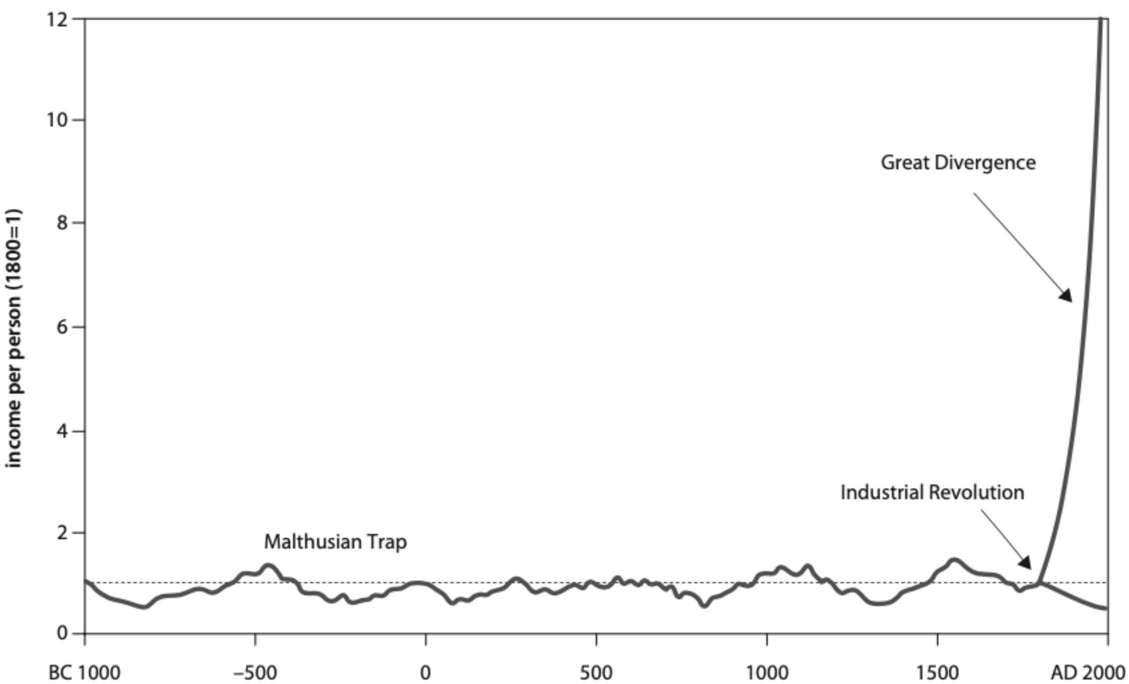

Figure 1. Very stylized facts: economic historian Greg Clark's made-up graph of long-run prosperity

Not all social scientists want to go quite that far. Plenty accept that prosperity increased with the coming of agriculture, starting roughly ten thousand years ago in the Middle East, before it surged upward in early-modern western Europe. Some, however, interpret the agricultural revolution as actually hardening the Lucas-Clark vision, concluding that farming made the desperately poor hunter-gatherers of the Ice Age poorer still and that the contrast between preindustrial and industrial prosperity was even greater.[5] The geographer Al Crosby sums up the general view neatly: "between that era [of domestication] and the time of development of the societies that sent Columbus across the Atlantic, roughly 4,000 years passed, during which little of importance happened."[6]

All these theories are wrong. Even calling them Malthusian, as their champions generally do, is wrong. Malthus himself was very clear that his work laid bare the relationship between food and population and was not a general account of prosperity. "It should be remembered always," he insisted in a passage that is almost universally ignored, "that there is an essential difference between food and those wrought commodities, the raw materials of which are in great plenty. A demand for these last will not fail to create them in as great a quantity as they are wanted. The demand for food has by no means the same creative power." Like every classically educated gentleman of his age, Malthus knew perfectly well that prosperity in "wrought commodities" had increased particularly rapidly in ancient Greece and Rome, and that a society could simultaneously be rich such commodities but poor in food.[7]

These theories are mistaken, I believe, because they do not take our evidence about the past seriously enough. This evidence shows two things: first, that we humans have been increasing the amount of energy we capture, the efficiency with which we use it, and the range of ends to which we apply it (in short, increasing our prosperity) ever since we evolved; and second, that the evolution of prosperity is in fact a universal process.

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Universal Growth

If that were not so, none of us would be here to enjoy this conference. One of the more depressing discoveries of nineteenth-century science was that, other things being equal, all complex arrangements of matter will decay, until the entire universe reaches thermodynamic equilibrium—a state in which energy and matter are smoothly distributed across space and time in an undifferentiated mush. Entropy, says the historian David Christian, is a "thermodynamic down escalator," carrying everything—atoms, stars, planets, people—inexorably toward non-existence.[8]

Fortunately, that has not (yet) happened, because forces of several kinds allow complex arrangements of matter to persist through time by capturing enough free energy from their environments to keep their place on the escalator or even to run back up it. In the beginning, say cosmologists, everything was tiny and simple, the entire universe fitting into an almost infinitely tiny, dense, homogeneous, and hot dot. In the first fraction of a second that it existed, this dot became dramatically bigger and more complicated, expanding faster than the speed of light to the size of an entire galaxy. Time, space, matter, and energy separated out from the primordial flux, and the fundamental force of gravity began clumping the cooling matter into subatomic particles. In the next three minutes, electromagnetism fused protons and neutrons into hydrogen and helium nuclei, which, given another 300,000 years, trapped electrons to become atoms. Another billion or more years saw gravity collapse vast clouds of gas into balls just a million or two miles across, separated by yawning gulfs of nothingness. Under intense pressures, the cores of these gas balls turned into nuclear reactors: stars lit up the infinite darkness. Hydrogen and helium combined into heavier elements, which were caught in stars' gravitational fields and molded into asteroids, planets, and moons. Some of these bodies had enough gravity of their own to trap gassy atmospheres, and in at least one atmosphere, right here, blobs of carbon came to life. Over the next 3.4-4.4 billion years, the blobs turned into us; and the rest is history.[9]

The astrophysicist Eric Chaisson calls this process "cosmic evolution," and measures it in terms of what he calls "energy rate density"— the amount of energy flowing through each gram of any complex cluster of matter each second, expressed as ergs per second per gram (erg/s/g). The oldest arrangements of matter, protons and neutrons, trot along slowly on the escalator's bottom steps, being able to hold themselves together on a budget of less than one-hundredth of an erg per second per gram (erg/s/g). Even stars and planets can manage on barely 10 erg/s/g. But newer arrangements of matter have raced up the escalator (Figure 2). The earliest human societies needed roughly 40,000 erg/s/g, while ancient empires like the Roman and Han Chinese required seven or eight times as much. Our twenty-first-century technological economies burn through a whopping 2 million erg/s/g.[10]

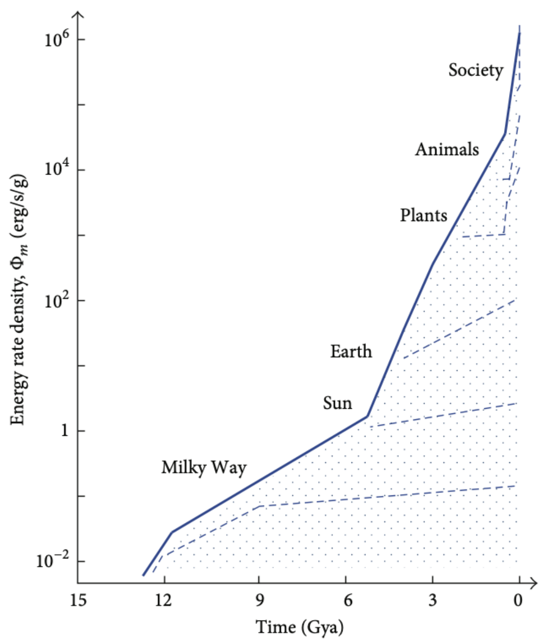


Figure 2. The real dawn of everything: astrophysicist Eric Chaisson's graph of cosmic evolution, measured in ergs per second per gram across the last 13.8 billion years

At the highest level of abstraction, the 13.8-billion-year story of cosmic evolution is all much the same: some force captures enough free energy to move some arrangement of matter up the down escalator. The levels likely to be of interest here, however, call for finer distinctions. One is between the physical (which, for Chaisson, includes chemical) version of evolution and the biological kind. Somewhere between 3.4 and 4.4 billion years ago—"in some warm little pond," Darwin speculated—carbon began bonding to other chemicals to form blobs a dozen or two molecules long. These contained proteins and nucleic acids that could metabolize energy, repair some sorts of damage, and replicate themselves; and although biologists argue over how to define "life," most agree that these blobs reach the bar.[11]

Life, the physicist Erwin Schrödinger once said, is just an exquisitely efficient system for "continually sucking orderliness from its environment." Even the simplest algae consume 900 erg/s/g. But even more importantly than this, replication is always—as Darwin saw—"descent with modification." RNA, the simpler predecessor of the DNA in our own bodies, makes roughly one error in every 300,000 bases it copies, and while most of these make little difference to a new blob's reproductive chances and some affect them negatively, others improve the bearer's effectiveness at metabolizing energy, repairing itself, or replicating. Thanks to copying errors, says biologist Richard Dawkins, blobs became "survival machines," vessels that improved their genes' potential to be passing on to a new generation. In a world where energy was finite and organisms had to compete to capture it, Dawkins explains, "making a living steadily got harder as new rivals arose with better and more effective survival machines. Survival machines got bigger and more elaborate, and the process was cumulative." The physician Siddhartha Mukherjee puts it nicely—"freaks became norms, and norms became extinct. Monster by monster, evolution advanced."[12]

Natural selection did not automatically promote bigger, more complex organisms that ran faster up the down escalator. "The most salient feature of life on this planet," the biologist Stephen Jay Gould reminds us, "has been the stability of its bacterial mode from the beginning of the fossil record until today … This is truly the 'age of bacteria'—as it was in the beginning, is now and ever shall be." Only under rare circumstances would it be to a survival machine's benefit to undergo mutations that made it bigger, helped it capture more erg/s/g and use them more efficiently and in new ways; but once in a while, a freak or monster would find that these abilities paid for themselves. Descent with modification gave some organisms gills, lungs, fins, legs, leaves, roots, eyes, and brains. Some brains supported minds conscious of themselves; some minds even created culture.[13]

"Culture" is just as difficult to define as "life." Again sidestepping rather than hacking though a terminological thicket, I approach I find most useful is the biologist Peter Richerson and anthropologist Robert Boyd's, seeing culture as "information capable of affecting individuals' behavior that they acquire from other members of their species through teaching, imitation, and other forms of forms of social transmission."[14] All animals are capable of acquiring information through instinct, but only some can do so through culture. Birds are a good example: babies brought up by their parents learn different songs from those raised away from them. Similarly, while chimpanzees in Tanzania's Gombe Park learn to catch ants by poking long sticks into their mounds, pulling out insects, and using their fingers to pop them into their mouths, chimps in Côte d'Ivoire's Tai Forest learn to use short sticks and to bite the ants directly off them. Crows, orangutans, dolphins, whales, and plenty of other animals can be said to possess culture. However, say Richerson and Boyd, human culture goes far beyond theirs. We alone are capable of *cumulative* cultural evolution. "In nonhuman animals," Richerson and Boyd explain, "social learning leads to the spread of behaviors that individuals could, and routinely do, learn on their own." Humans, however, are also capable of "the gradual, cumulative assembly of adaptations over many generations, adaptations that no single individual could evoke on his or her own."[15]

Over the last few million years, prosperity—higher energy rate densities—has been the most obvious side-effect of cumulative cultural evolution. However, it is not the only possible side effect. Like biological evolution, cultural evolution is undirected, and if behavior that lowers energy rate densities is the most successful adaptation to a particular environment, people who choose to act that way will flourish at the expense of those who do not, and humanity will start being carried back down the entropic escalator. In other ways, though, cultural evolution differs from biological evolution as much as biological evolution differs from physical. Three differences seem particularly important.[16]

First, while biological evolution works its magic through selective pressures operating on random genetic mutations, cultural evolution works through human choice operating on behaviors that are generated by non-random decisions. Intentions and agency are therefore fundamental to cultural evolution. However, we can never see inside the heads of people in the past to understand their intentions (most of us find even our own motivations difficult to understand). The only solution seems to be to fall back on an abstraction like the old idea of utility (more in the Jevons sense than the Bentham):[17] that the ideas that succeed are those that, in a particular environment, the greatest number consider to being the greatest good.

Second, cultural evolution differs from biological in acting horizontally as well as vertically. While we inherit genes only from our parents, we can pick up ideas from anyone. Cultural evolution therefore has the potential to work much faster than the biological kind, with the size of the learning community, institutions that enable the sharing of ideas, and values that reward learning all acting as multipliers.

Third, while the unit of selection in biological evolution is always the gene, cultural evolution works at multiple levels, from the gene up to groups billions strong. However, it can only operate at larger scales if the benefits that cooperation confers at that level outweigh the costs it imposes at lower levels. This was already evidence to Darwin: "A tribe possessing … a greater number of courageous, sympathetic and faithful members, who were always ready to warn each other of a danger, to aid and defend each other," he observed, "would spread and be victorious over other tribes." The result, he concluded, was that "the social and moral qualities would tend slowly to advance and be diffused throughout the world"—and so too prosperity.[18]

Measuring Long-Run Prosperity

The only way we can know if a long-term, evolutionary perspective is the best way to think about human prosperity is by measuring energy rate densities, but there have been surprisingly few attempts to push measurement very far into the past. So far as I know, the first stab at it was made by the geoscientist Earl Cook in 1971 (Figure 3). Cook estimated that daily energy use had risen by three orders of magnitude across the last 2 million years, from about 2,000 kilocalories per person among *Homo habilis* to 230,000 in 1970s North America.[19]

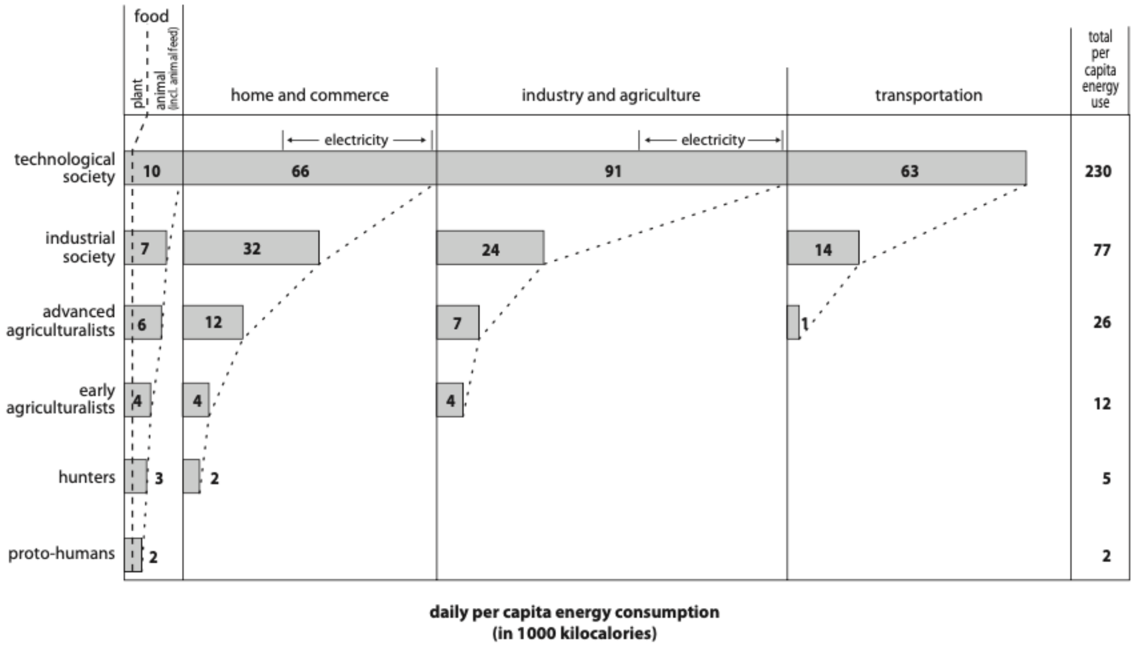


Figure 3. Earl Cook's estimates of per capita energy consumption across the last 2 million years

Infuriatingly, Cook provided no sources for his figures, but when I tried to improve on his guesstimates by gathering data from just the last sixteen millennia, I consistently ended up with numbers near his (Figure 4). Grounding estimates empirically is no simple business, requiring combinations of archaeology, primary texts, and ethnographic observation, crosschecked whenever possible by studies in energetics. There will always be room for argument over the definition of terms and particular figures.[20] Yet the overall pattern is glaringly clear: while we have certainly been running up the down escalator very much faster in the last two centuries than we ever did before, the vulgar Malthusian theory is dead wrong that nothing happened till 1800 CE. So too the modified version that something did happen around 8000 BCE, but then nothing else of significance happened for nearly ten thousand years. Instead, we see that energy rate densities have nearly always (although not absolutely always) grown exponentially, with the exponent increasing over time. Growth was very slow between the starting point of my index (around 14,000 BCE) and the beginnings of plow agriculture (around 6000 BCE in the Middle East), but then accelerated, and did so more after the creation of the first governments (again in the Middle East, around 3000 BCE) before it shot upward with the creation of intercontinental exchange networks (organized around Western Europe, beginning around 1600 CE) and the unleashing of fossil-fuel energy (Western Europe once more, around 1800 CE). There have also been periods when energy capture stagnated, and even ones when it fell for centuries at a stretch, such as 1200-1000 BCE and particularly 100-600 CE (energy capture did not regain Roman levels until about 1100 CE, in Song dynasty China). Over the last sixteen millennia, the growth of prosperity has been uneven and interrupted, but relentless.[21]

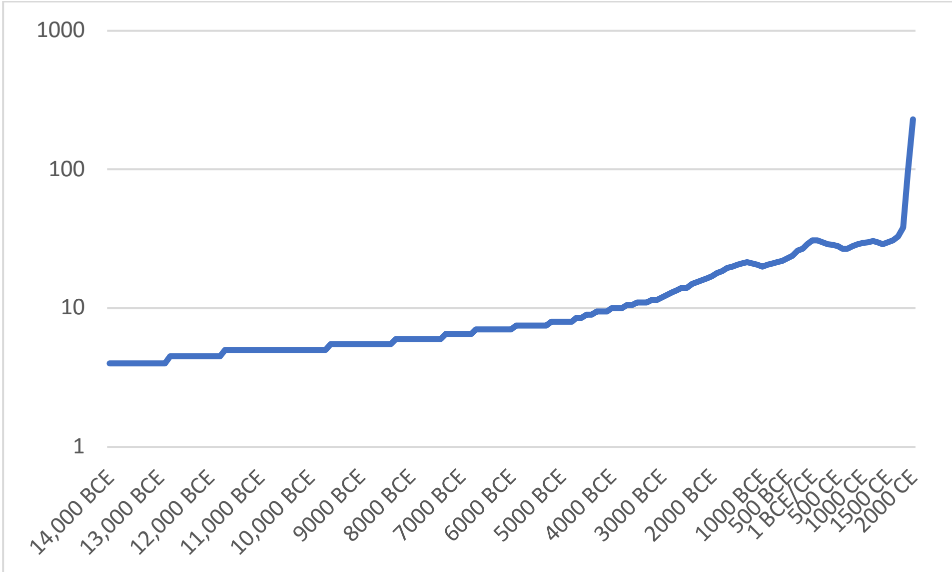
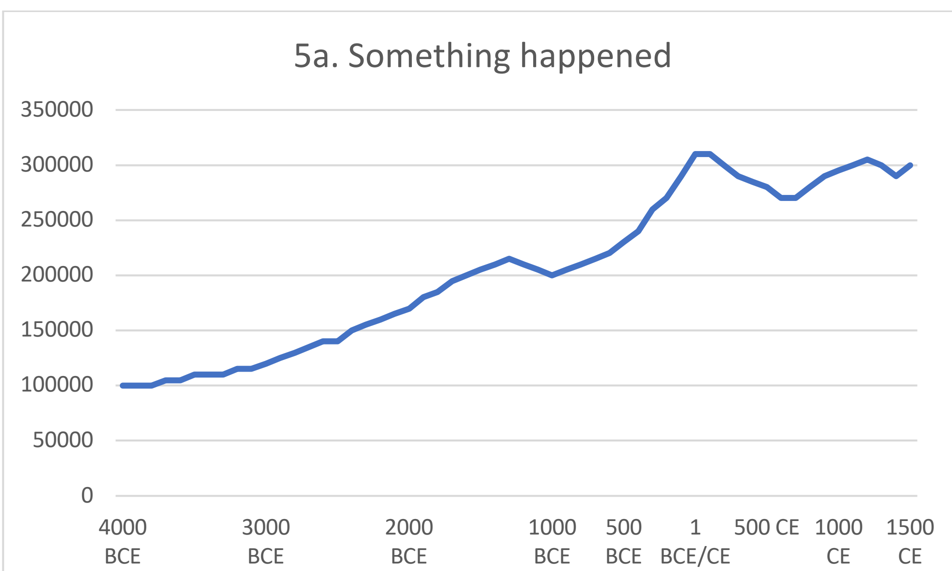


Figure 4. Peak energy capture, 14,000 BCE-2000 CE, measured in kcal/cap/day (the scale on the *y* axis is logarithmic)

The reason social scientists have had trouble seeing this, I suspect, is a pervasive tendency to see everything from our own twenty-first-century perspective. Figures 5a and 5b both show on a linear-linear scale my energy capture years for the period 4000 BCE-1492 CE, the era "during which," Crosby claims, "little of importance happened." However, while Figure 5a just shows those years, Figure 5b extends the graph to 2000 CE. If we view the past from a modern perspective, in which economies are known to grow at 10 percent per annum, Crosby's assertion makes sense; but if we view the past from the inside, as it were, seeing it from the perspective of the people who actually lived through it, his argument looks entirely wrong. A very great deal happened in history.



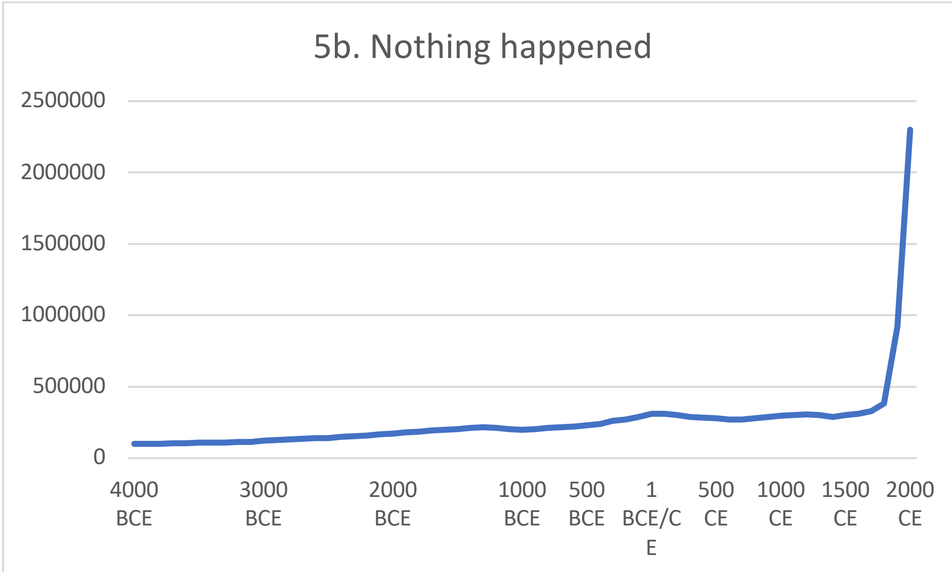


Figure 5. Lies, damned lies, and statistics: two ways to show energy rate densities, 4000 BCE-1500 CE, expressed as erg/s/g. Viewing the data from the lofty perspective of the year 2000 CE, as in Figure 5b, renders all earlier changes almost invisible; viewing them from the perspective of the people who lived through them, as Figure 5a does, reveals relentless but uneven and interrupted growth

There are other ways to run the numbers, but all end up in rather similar places. Figure 6 shows some calculations I made of the relative sizes of the world's total population and several kinds of political, cultural, and economic communities in 1000 BCE, 175 CE, and 1350 CE (all three points falling in Crosby's nothing-happened era). Average incomes probably grew less than 50 percent between 1000 BCE and 175 CE, then fell back some way by 1350 CE, but the population of the largest states grew thirtyfold between 1000 BCE and 1350 CE and religious communities even more. Other kinds of comparisons reveal just as much variation. Skeletal analysis largely confirms Malthus' insight that diets and health were typically no better in Columbus' day than they had been in 4000 BCE, even the briefest comparison of excavated houses dating around 1500 CE with those four, five, or six millennia older leaves no doubt that in terms of Malthus' "wrought commodities," prosperity increased dramatically (by my estimate, roughly tripling). The minute we take the evidence for energy capture seriously, only one conclusion is possible—that prosperity has been growing relentlessly, albeit unevenly and with regular interruptions, as far back as we can see. We are *Homo augens*.[22]

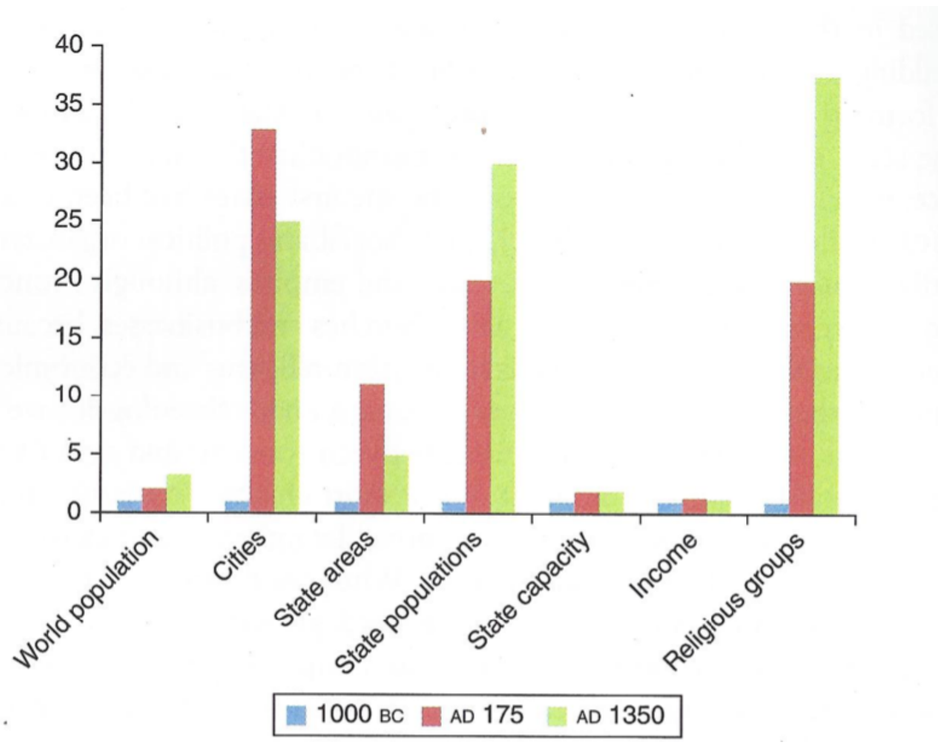


Figure 6. Mixed growth: the scale of selected organizational forms in 1000 BCE, 175 CE, and 1350 CE. For each, the size in 1000 BCE = 1

Prosperity in the Very Long Run

For many purposes, tracing a phenomenon across sixteen millennia would count as very long-term history, but it is nowhere near long enough for my claim in this paper that we must locate prosperity within a story of cosmic evolution. If I am right that humans are *Homo augens*, "Growth Man," I need to go back all the way to the beginning—which, depending (once again) on how we define our terms and interpret problematic data, is somewhere at least 45,000 years ago, and quite possibly 1.8 million years ago. That is something I am trying to do in the book I am currently writing, modestly titled *What Happened in History*,[23] but right now, I will just offer a few empirical snippets to support my assertion that—allowing for unevenness and interruptions—rising energy rate densities are at the heart of the human condition.

The first question has to be when biological evolution made our apish ancestors capable of cumulative cultural evolution. This is essentially a question about their cognitive abilities, but these cannot be separated from the evolution of the rest of their bodies. Darwin, as usual, saw to the heart of the matter: "Man could not have attained his present dominant position in the world," he flatly asserted, "without the use of his hands, which are so admirably suited to act in obedience to his will." Childe put it even better: the secret of humanity's success, he said, "may be summed up in two words, hands and brains." Despite a profusion of prolixity, paleoanthropologists still agree. "The evolution of bipedal locomotion," says one, "enhanced the proprioceptive and haptic potentialities"—meaning that the mutation of our front feet into hands not only allowed us to make things but also rewarded the evolution of richer neural pathways.[24] The famous footprints that Mary Leakey found at Laetoli in Tanzania illustrate hominins walking upright 3.7 million years ago—although shoulder and elbow joints also show that *Homo habilis* still spent much of their time in trees 2 million years ago.[25]

Paleoanthropologists have long defined the genus *Homo* by the ability to make flaked stone tools. Primatologists now know that chimpanzees and monkeys not only use stone tools but also create artificial blades; but stone tools remain a useful (and archaeologically visible) proxy for the ability to think several steps ahead in manufacture, the dexterity to manipulate materials, and to some degree for increased energy capture. The oldest stone blades currently known, from Lomekwi in Kenya, date back 3.3 million years; but a microscopic study of 3.4-million-year-old mammal bones from Dikika in Ethiopia revealed cut marks that could only have got there if hominins were using stone tools to slice off meat.[26]

It now seems likely that hominins actually hunted other animals, rather than just being parasites who picked carcasses clean after big cats and hyenas had finished with them, and the ability to capture extra calories from meat-eating features heavily in most theories of encephalization, the growth of brain size relative to body size. The hominin encephalization quotient has more than doubled in the last 4 million years (Figure 7).[27]

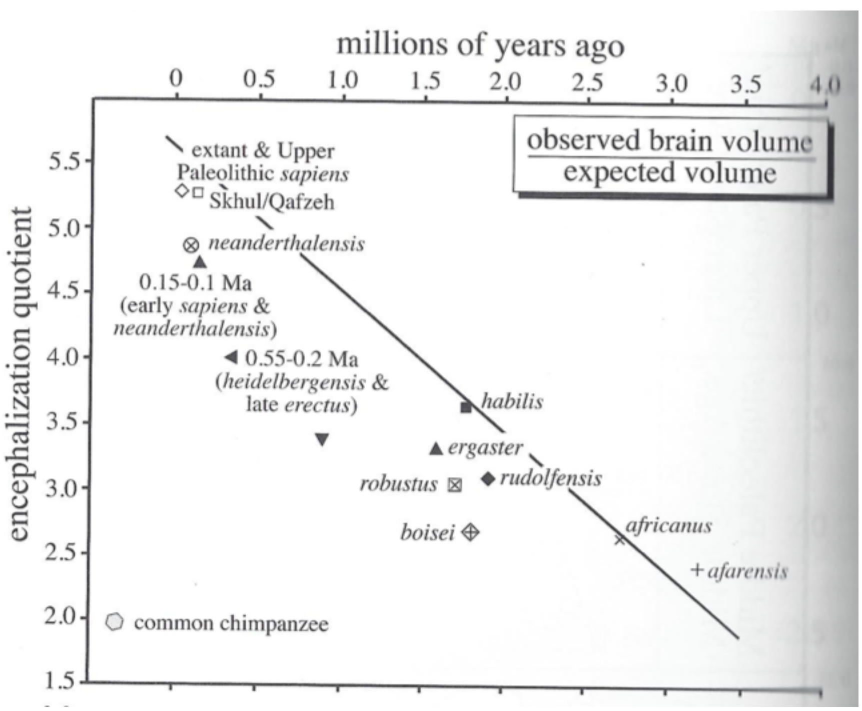


Figure 7. Big heads: encephalization quotients across the last 4 million years

By 2 million years ago, *Homo habilis* was already a more prosperous ape than modern chimps or gorillas, and had expanded its range from Africa to China. However, most paleoanthropologists are skeptical about whether it was capable of genuinely cumulative cultural evolution. Some even consider it so unhuman that they call it *Australopithecus habilis*.[28] There is much more scholarly support for considering *Homo ergaster*, a taller, more gracile, less hairy, and much bigger-brained ape that evolved in Africa around 1.8 million years ago, as the originator of cumulative culture. Their bodies required a caloric intake 50-100 percent higher than *habilis*, and changes in the shape of ribcages show that they managed to absorb this despite having shorter intestines. The anthropologist Richard Wrangham has suggested that they accomplished this by figuring out how to cook meat, making its calories easier to digest. The archaeological evidence does not entirely fit the theory, but *ergaster* certainly found some way to process energy more efficiently to feed their bigger brains.[29]

Part of their gains in efficiency came from superior tools, including hafted weapons, but *ergaster* also seem to have organized life differently from earlier hominins. While *habilis* campsites look rather like modern chimpanzees', *ergaster* seems to have behaved more like modern human foragers. They created base camps at good water sources, with multiple groups (pair-bonded families?) each having their own activity areas within them. From these sites small parties would strike off to set up temporary camps devoted to specialized activities (hunting and butchering particular animals, collecting stone, etc.), just as modern foragers do. Skeletal lesions suggest that *ergaster* sometimes cared for sick or injured companions long enough for pathologies to manifest themselves on their bones; a 500,000-year-old carved shell from Trinil in Java looks to some eyes like the world's oldest artwork; and the fact that enough *ergaster* crossed twelve miles of open water to establish a viable breeding population on Flores in Indonesia suggests to some that they could either talk or do something very like it.[30]

Although controversy swirls around whether *ergaster*'s spinal columns were wide enough for them to control their breathing in the way needed to form words, few anthropologists doubt that they were more capable of cultural evolution than any earlier animal. But even so, questions remain over whether how cumulative their culture was. The innovations listed above are spread over a million years, and while they definitely increased energy rate densities, they could well reflect not what the psychologist Michael Tomasello calls the "ratchet effect" of our own brains but simply the slow, biological evolution of brains able to imagine new things but not to tinker and tweak. Not until about 300,000 years ago does the case for cumulative cultural evolution start to become compelling.[31]

A cluster of radically new behaviors appeared. Most important was mastery of fire. It is possible that *Homo ergaster* had been able to kindle fire 800,000 or even 1.5 million years ago, but between 350,000 and 250,000 years ago hominins in Europe clearly learned to make fire at will. This massively increased not only their energy capture but also the efficiency and range of ways that energy could be used—most obviously, by burning wood for warmth and to cook, but also by burning forests to stampede game and clear patches where edible foods could grow (thereby also attracting more game to feed on them).[32]

Along with fire came new tools, known as the Levallois style after the Parisian suburb where they were first found. These gave toolmakers greater control over the final product's shape while minimizing the amount of stone wasted. Having spent an embarrassing amount of time trying and failing to chip my own Levallois tools as an undergraduate in a flintknapping class, I feel confident in saying that these were products of cumulative cultural evolution. Ingenuity like this required not just teachers as patient as the ones I disappointed but also generations of artisans, adding tweaks and passing them on.[33]

The third great innovation was turning energy into something new: art. Throughout prehistory, humans used ocher, a naturally occurring mix of iron ore, clay, and sand, to decorate cave walls and their dead. Around 300,000 years ago, Africans began regularly walking 25-35 miles to collect it. They must have had compelling reasons for doing so.[34]

One more piece of biological evolution might explain these changes: the emergence of us. Domed crania like those that define *Homo sapiens* first appear at Jebel Irhoud in Morocco around 315,000 years ago, and it would be convenient to assume that the bloated neocortices that our skulls accommodate explain the beginnings of cumulative cultural evolution and of *Homo*'s ability to run faster up the down escalator. Richard Wrangham even suggests that *sapiens* 300,000 years ago were the first hominins able to talk, and that they used this new power to form bands of males able to restrain would-be alphas. However, the first hominins to use fire habitually and make Levallois tools were definitely not *sapiens*. Most paleoanthropologists now think that *Homo* of all sorts were evolving human-like cognitive powers by 300,000 years ago. Neanderthal, Denisovan, *sapiens*, and other cognitions were probably distinct, but we *sapiens* seem not to have had any particular intellectual advantage over our cousins at this point. Until about 50,000 years ago, every kind of behavior once seen as unique to *sapiens*—from burying the dead through art to religious ritual—was shared by multiple kinds of *Homo*.[35]

Right up until that point, there remains at least some room to dispute the cumulativeness of hominin cultural evolution. Energy rate densities were certainly higher 50,000 years ago than they had been 500,000 years before that, but changes were so slow that some experts hold that they were still the products of biological, not cultural, evolution. This theory was very popular in the late twentieth century, when it became clear that although humans had looked more or less like us by 200,000 years ago, they had not acted like us, in the sense of rapidly accumulating culture, until 50,000 years ago. The explanation, some experts suggested, was that despite having a modern-looking neocortex, *sapiens*' brains needed an anatomically invisible neurological mutation to rewire them before they could work like ours. Only then, it was suggested, did *sapiens* brains turn into the parallel-processing miracles that we all carry around at the top of our bodies—for all we know, the most advanced piece of biological evolution in the universe.[36]

The obvious possibility was that some gene or combination of genes switched on around 50,000 years ago, and in the early 2000s attention focused particularly on *FOXP2*, which codes for a protein influencing how brains process speech and language. However, geneticists have now shown that Neanderthals too had FOXP2 and that there is no sign of any positive selection on *FOXP2* in *sapiens* around the relevant date. Detailed reviews of the archaeological data also showed that there are in fact signs of slow but cumulative cultural evolution going back at least 100,000 years.[37]

Instead of an *ignotum per ignotum* theory ascribing everything to biology, most archaeologists now suspect that several kinds of *Homo* were cognitively capable of cumulative cultural evolution by 300,000 years ago at the latest. The reason that cumulative cultural evolution was so glacially slow until 50,000 years ago, most think, was that there were just too few humans around, too thinly scattered over too great distances, for new ideas and skills to accumulate faster than old ones were lost through copying errors and/or the extinction of tiny, nonliterate bands. Economists call this the "empty planet" phenomenon, in which innovation rates decline toward zero as population falls below critical thresholds, but anthropologists have long known that rates can actually fall below zero. Using straightforward mathematical models, the anthropologist Joseph Henrich calculates that once a pool of learners shrinks below 4,000, complex skills will start to disappear. Below 1,000, even quite simple skills can easily be lost, and people constantly have to reinvent the wheel (so to speak—contrary to caveman cartoons, wheels were only invented 6,000 years ago).[38]

The classic case is Tasmania, which was cut off from continental Australia by rising sea levels 10,000 years ago. Initially, the few thousand hunter-gatherers isolated there carried on living like the mainlanders nearest them, but finds from excavations suggest that somewhere around 6000 BCE, they stopped carving bones into needles, fishhooks, and barbed spears. By 3000 BCE, fish bones were becoming rare, and by 1800 BCE, they disappeared altogether. By 1000 BCE, so had the last bone tools. The archaeologist Rhys Jones, who identified this pattern, speculated that Tasmanians also stopped meeting in large groups (crucial for accumulating culture) and lost the use of fire. It gets cold in Tasmania, but when Captain Cook arrived in 1777 CE, he found the locals—who lacked needles to sew animal skins together—shivering through the winters wearing nothing more than a single wallaby pelt slung over the shoulders and ocher and grease smeared over exposed skin. Nor is Tasmania the only example. When an epidemic killed most of their elders in the 1820s CE, the Polar Inuit in northern Greenland were left with no one who knew how to build kayaks. Unable now to go fishing, their population fell further and more skills disappeared. By the 1850s, they could only hunt seals seasonally and could no longer catch caribou at all. Disaster was averted only when a group of Baffin Islanders arrived in 1862 and reintroduced the lost techniques.[39]

DNA suggests that as recently as 150,000 years ago, there were still only about 16,000 *sapiens*, spread all across Africa. Neanderthals were even rarer: their DNA suggests that there were never much more than 10,000 of them, scattered from England to Uzbekistan. The geneticist Laurits Skov concludes that Neanderthals were always "an endangered population," teetering on the edge of extinction. Around 70,000 years ago, however, for reasons that are hotly debated, *sapiens* began a population explosion. After crossing into the Middle East 70,000 years ago, a group of a few hundred or at most a few thousand multiplied madly. Their distant descendants reached Indonesia and Australia about 60,000 years ago, Siberia and Europe 45,000 years ago, and China 40,000 years ago. Entering the New World, they left footprints in Utah 22,000 years ago and reached the Andes 3,500 years after that, and emigrants from East Asia settled most of Oceania in the last few thousand years.[40]

In Europe, *sapiens* were ten times thicker on the ground 45,000 years ago than Neanderthals had ever been. They created a new cultural package, defined by the archaeologist Stephen Shennan and geneticists Adam Powell and Mark Thomas as "consistent presence of symbolic behavior, such as abstract and realistic art and body decoration (e.g., threaded shell beads, teeth, ivory, ostrich egg shells, ochre, and tattoo kits); systematically produced microlithic stone tools (especially blades and burins); functional and ritual bone, antler, and ivory artifacts; grinding and pounding stone tools; improved hunting and trapping technology (e.g., spear throwers, bows, boomerangs, and nets); an increase in the long-distance transfer of raw materials; and musical instruments, in the form of bone pipes." From that point on, innovation has been pervasive, and as population densities on other continents approached European levels, the humans in them followed similar paths of cumulative cultural evolution.[41]

Cultural accumulation remained so slow that it would hardly ever have been visible on the scale of an individual lifetime, and it has regularly been interrupted, but there have never been shocks on anything like the scale needed to return the world to the glacial pace of earlier times. *Homo* has been unambiguously *augens* for at least 45,000 years, and energy rate densities have increased faster and faster. By roughly 25,000 years ago, some Europeans were hunting and gathering effectively enough that they could settle more or less year-round in villages of 100+ people, where they built sturdy houses, dug wells, made thousands of clay figurines, and traded valued goods across hundreds of miles. They dramatically expanded their kit of stone tools, extended their killing range with spear-throwers, and used nets and harpoons to trap fish. As well as working out how to smoke and store meat and fish, they learned to grind seeds and acorns then bake the flour into bread. "It seems likely," says paleoanthropologist Richard Klein, that Europeans "had devised the entire range of technology observed among historic hunter-gatherers."[42]

By 20,000 years ago, Middle Easterners had embarked on what archaeologists call the Broad-Spectrum Revolution, inventing methods that effectively lowered the cost of hunting small game and gathering abundant but not especially nutritious small-seeded plants to the point that these became economic food sources. This hugely increased the calories they captured. Over the next 10,000 years, humans on every continent figured out similar strategies. Excavations on Middle Eastern sites in what were, in the Ice Age, fertile wetland have yielded what botanists call "proto-weeds," plants that flourish only in heavily disturbed soils, which almost certainly means that as early as 20,000 BCE villagers were planting gardens that they dug over, weeded, fertilized, and perhaps even watered.[43]

Cultivation transformed the selective pressures operating on plants, particularly the annual cereals that flourished in zones of the Old World between the Middle East and China. Roughly one wild wheat or barley plant per million carries a mutation that leads its seeds to remain on the stem rather than drop to the ground to grow a new plant—a disastrous mutation under natural conditions, because it will cause that plant to die without offspring, but highly advantageous for humans harvesting the plant, because all of that plant's seeds will stay in place for them to eat, increasing the energy they capture. The spread of this mutation through an entire gene pool is the process that botanists call domestication. Experiments have shown that, other things being equal, this mutation should conquer a cultivated cereal's genome in just one to three centuries, leaving the plant's reproduction entirely dependent on our willingness to replant their seeds—and often leaving us more than willing to do this, because domesticated cereals regularly yield twice as many calories per calorie of labor expended as wild ones.[44]

In reality, however, other things are never equal, and archaeologists have find no domesticated seeds at all on sites dating before about 9000 BCE, even though Middle Easterners had by then been cultivating cereals for ten millennia. The decisive change was exogenous: the end of Ice Age conditions around 9650 BCE made the weather warm, wet, and above all stable enough for domesticated plants to make headway. Before 9650 BCE, crop failures were so common that they wiped out domesticated and wild plants alike long before domestication could get anywhere. But after 9650 BCE, without gardeners changing their behavior in any way, mutant seeds that stayed on the plant until harvesters came along slowly triumphed (as Mukherjee put it, monster by monster, evolution advanced).[45]

In the Middle East, the process took over three thousand years (archaeological samples dating before 9000 BCE contain no domesticated seeds, but those from 6000 BCE often contain only domesticated seeds), and people in several other parts of the world (particularly China, Mesoamerica, the Andes, Amazonia, eastern North America, and the Sahel) independently domesticated their own wild plants over the next several millennia. All these agricultural revolutions were alike in the senses that they increased energy capture, that farmers always found ingenious ways to improve the efficiency with which they used the extra ergs, and that specialists always emerged to show how the energy could be used in new ways; but in other senses, because they happened in different places, where different sets of wild plants and animals had evolved, each agricultural revolution was also unique.

One major distinction was between seed-based and tuber-based cultivation. Seeds normally have to be harvested at a particular time of year and then stored, making them very vulnerable to predation (by other humans as well as other animals) and encouraging territoriality and protection rackets; tubers can normally be left in the ground until needed, making them much harder to tax. By and large, energy rate densities increased much faster in seed-based economies than in tuber-based ones, but also much more unevenly. This is why, says the anthropologist James Scott, complex, hierarchical states have generally been "grain states"—and also why, despite modern talk of "banana republics," in reality "no … taro states, sago states, breadfruit states, yam states, cassava states, potato states, peanut states, or banana states [have] appeared in the historical record."[46]

Every bit as important as the distinction between seeds and tubers was that between economies with large domesticated mammals and those without them. In the Middle East, the practical constraints of cultivating domesticated cereals by hand meant that no gardener could farm more than an acre or two, making it very difficult for even the most industrious to grow much richer than anyone else. Somewhere around 6300 BCE, however, agriculturalists worked out how to harness domesticated cattle to plows, augmenting their own labor with animals' muscles, doubling or tripling the amount of land a family could farm. Total energy capture grew faster, and prosperity along with it, allowing people to build sturdier homes and fill them with far more material goods. However, what grew fastest of all was unevenness in the distribution of the fruits of growth, particularly when farmers started breeding oxen (bigger, specialized draft animals) somewhere between 4500 and 4000 BCE.[47]

In a process archaeologists call the "secondary products revolution," farmers found countless new ways to process, store, and trade the fruits of their labors more efficiently. They invented sailing ships and wheeled carts, learned to weave fibers and wool into clothes, and started casting copper tools, weapons, and ornaments. They created symbols to mark and account for private property, and by 3300 BCE or so had turned these into genuine writing. Managers took charge, making themselves into powerful chiefs as early as 4400 BCE. By 3100 BCE, Egyptian chiefs had become kings so awe-inspiring that multitudes were apparently willing to believe that their leaders were gods on earth.[48]

Those areas of Eurasia that also had cereals and draft animals—such as China and India—went down similar paths in the third millennium BCE, and by 1 BCE conquest, colonization, and copying had spread the grain-based states package across Europe, Central and Southeast Asia, and into sub-Saharan Africa. In the New World, however, almost all large animals had gone extinct by 6000 BCE, and agriculture always depended on human labor. Ingenious farmers found ways to squeeze a lot out of the land and ingenious rulers found ways to squeeze a lot out of the peasantry, building spectacular monuments in Mesoamerica, the Andes, and occasionally Amazonia and North America; but neither growth nor prosperity ever matched the Old World's. American energy capture and population were always lower, writing and metallurgy remained rudimentary, and wealth inequality was muted by Eurasian standards. The Roman and Han Empires each ruled 60 million or more subjects by 1 BCE, but contemporary Zapotec and Moche states in the Americas were barely one-tenth that size. In Eurasia, Chang'an had around 500,000 residents by 1 BCE and Rome a full million, but no ancient American city surpassed 100,000 (at Teotihuacan around 200 CE).[49]

Eurasians kept finding ways to build on the cereal-and-plow model. Generally, there were shifts away from absolutist monarchies toward somewhat more corporate structures, as well as endless technical improvements lowering transport, communication, and transaction costs. Greek and Roman networks in the first-millennium-BCE Mediterranean probably went furthest, integrating tens of millions of people into marketing networks.[50]

Looking back to Figure 5, however, one further detail requires comment. Energy rate densities generally rose from 4000 BCE until they reached a peak of about 300,000 erg/s/g somewhere in the first centuries CE, but when Columbus sailed to the Americas in 1492, they were still around the same level. That, I have suggested in earlier books, was because societies like the Roman Empire around 100 CE, Song China around 1100 CE, and Europe, Turkey, India, and China around 1700 CE had run just about as far up the down escalator as was possible in a purely agrarian world, where "time marched to the dull rhythms of foot and hoof" (as the historian Kyle Harper puts it). All these societies had stretched communication and transport technologies, financial institutions, and military capacity to their limits, and all sprawled across multiple biomes and previously distinct disease pools. All were exceptionally sensitive to external shocks that made the utility of such large, hierarchical, energy-guzzling organizations much less obvious.[51]

Time and time again, the same five forces overwhelmed ancient empires' resilience: (1) population movements too large for the institutions of the day to handle; (2) epidemic diseases carried by merchant and migrants; (3) the failure of states overwhelmed by collapsing frontiers and mortality spikes; (4) the breakdown of the long trade routes that had fed the crowded cities; and, always present somewhere in the mix, (5) the unpredictable effects of climate change. In the first few centuries CE, interconnected crises brought down every great ancient civilization, from Italy to China. In the aftermath, smaller, less organized states and federations filled the void, and energy rate densities declined. Not until 1100 would any city (Kaifeng in China) match ancient Rome's scale, sophistication, and energy rate density—only for the Song Empire to break down much as the Roman had done, as new crises tore across Eurasia. In the seventeenth century, the Qing, Mughal, and Ottoman Empires and the nation-states of western Europe were once again pressing against the hard ceiling limiting agrarian economies, and crises were once again tearing them apart—only for Europeans in the eighteenth century to crack the secret of fossil fuels, unleashing an energy bonanza on an unimagined scale and opening the way to unprecedented prosperity.[52]

Conclusion

But that is a much more familiar story, and although I have strong opinions on why and how the fossil-fuel revolution happened, I will not rehash them here. My main point is simply that the modern surge in prosperity was not a bolt from the blue. Prosperity had already been growing for at least 45,000 years, probably 300,000 years, and possibly 1.8 million years, and in the very different forms of physical, chemical, and biological evolution, since time began 13.8 billion years ago.

The vulgar Malthusians are right that the surge in energy capture since the industrial revolution—doubling every 75 years or so, as opposed to every 2,500 years between 10,000 BCE and 1800 CE—makes mock of everything seen before. Converting premodern prosperity into contemporary dollars and cents is fraught with uncertainty, because so much is incommensurable; but in my own stab at it, building on Angus Maddison's rough-and-ready estimates, I concluded that the consumption level of the typical prehistoric forager equated to an income of roughly $1.10 per person per day (in 1990 international dollars), while that of the typical ancient peasant had risen to somewhere around $2.00 per day. In the richest ancient societies, like fourth-century BCE Athens, it may have reached the dizzying heights of $3.00-4.00 per day. In the World Bank's terms, premodern people went from being extremely poor to merely being poor. Only in the nineteenth century did middle-income countries, let alone rich ones, become a possibility. But that said, living on the equivalent of $3.00-4.00 per day would have seemed like luxury indeed to a forager managing on $1.10. The humans whose cumulative cultural evolution doubled or tripled their prosperity across ten thousand years were the first animals in the world (and perhaps the whole universe) to do anything like this.[53]

And that means that on the bigger issues, the vulgar Malthusians are wrong. Only by ignoring mountains of evidence can we claim that everyone before 1800 CE lived equally nasty, poor, brutish, and short lives. Cultural evolution, like biological evolution, is undirected, and when an environment makes lower energy rate densities more adaptive than higher ones—as was the case in much of Europe after 200 CE—people respond by riding the entropic escalator downward. Nor can we rule out the possibility that this will happen again. For at least 45,000 years, though, there has usually been utility in growth and prosperity, and people have pursued it. Our run up the down escalator was for millennia slow, uneven, and interrupted, but it was relentless all the same. We have always been *Homo augens*.

[1] https://www.dictionary.com/browse/prosperity, consulted October 15, 2022. Competing definitions are defended in Jackson 2009.
[2] I owe this label to my colleagues Hans Bork and Christopher Krebs, whose Latin is so much better than mine.
[3] There are some outstanding books on the long-term history of energy. White 1959 remains a classic, while Smil 2017 has most detail, Crosby 2006 is probably the most entertaining, and Christian 2004 is the most ambitious. Among older archaeological approaches foregrounding energy, Childe 1936 remains outstanding, despite the huge increase in our evidence; among recent long-term treatments, I have learned much from Kremer 1993 and Galor 2022.
[4] Lucas 2004 (incomes at 1985 values); Clark 2007: 1; Finley 1965: 12; Graeber and Wengrow 2021: 527 n. 1.
[5] Diamond 1997 is the most influential statement, with his preference for the second version made explicit in Diamond 1987. The first version was more popular in older scholarship (the essays in Braidwood and Willey 1962 were particularly upbeat).
[6] Crosby 2004: 42. He chooses a date around 3000 BCE for the beginning of his comparison because he takes that to be the time of the last major premodern domestication, of the horse. Geneticists and archaeologists are now in fact confident that the initial domestication was largely completed rather earlier, around 3500-4000 BCE (Librado et al. 2021), but that does not affect Crosby's claim.
[7] Malthus 1798: chapter 5; on Malthus' reading and subsequent distortions of his message, Mayhew 2014. Harper 2017 makes just this point about ancient Romans, who were simultaneously rich (by premodern standards) but sick (even by premodern standards).
[8] Christian 2004: 79-80.
[9] Krauss 2012; Carroll 2016.
[10] Chaisson 2010: 28; 2014.
[11] Darwin, letter to Joseph Hooker, February 1, 1871, cited from Follman and Brownson 2009: 1265; Trifonov 2011; Schrödinger, cited from Christian 2004: 80. In this and what follows, I draw on Margulis and Sagan 1995.
[12] Schrödinger, cited from Christian 2004: 80; Darwin 1859: chapter 4; Gout et al. 2017; Dawkins 1989: 19; Mukherjee 2016: 38.
[13] Gould 2006: 238.
[14] Kroeber and Kluckhohn 1952; Jahoda 2012; Richerson and Boyd 2005: 5.
[15] Baker and Cunningham 1985: 85-133; Tennie et al. 2009; Richerson and Boyd 2005: 107, 45.
[16] There are many discussions. I have found Dennett 1995, Richerson and Boyd 2005, and Mesoudi 2011 useful.
[17] Drawing here on the discussion in Collison Black 1972.
[18] Darwin 1873: Chapter 5. Bowles and Gintis 2011: 46-77 have an excellent introduction to multilevel selection.
[19] Cook 1971.
[20] Gregory Clark (2014) has been particularly critical of my scheme, but has concentrated almost entirely on definitional questions. He might be right that there are better ways to classify the data, but so far as I know, neither he nor any other scholar has shown what they are. When he does talk about data, as in his claim about "the hunter-gatherers of 10,000 B.C.E." that "their diet contained mostly meat, which derived from wild animals that consumed very large quantities of biomass per pound of meat eaten by the hunter" (Clark 2014: 825), he ignores the evidence we actually have. Until the 1990s, many archaeologists did assume that foragers in northern climates lived largely off red meat, but improved techniques for recovering floral remains and for measuring stable isotope ratios in bone chemistry now make it clear that even Neanderthals in Ice Age Europe consumed a remarkable range of plants (Higham 2021: 33, 255 nn. 7-10).
[21] Morris 2010: 135-71, 623-45, and in much more detail in Morris 2013. Plunging briefly into the weeds, I should explain that my goal in these books was different from Cook's: I set out to compare the social development of eastern and western societies over time, generating scores based on four traits, one of which was energy capture. Figure 4 shows my energy capture scores, combining the eastern and western data and showing the highest score in the world at any given date. My energy capture scores do not take into account increasing efficiency in energy use. The data suggest strongly that doing so would strengthen the pattern in Figure 4, but I could not find any straightforward way to operationalize efficiency. Nor does Figure 4 show the increasing variety of ways in which energy was applied over time, although my three other traits (information technology, war-making capacity, and organization, using the size of a region's largest settlement as a proxy for the latter) partially capture this.

[22] Morris 2019.
[23] Morris, in prep. My title is stolen from Gordon Childe's 1942 classic of the same name. Although the evidence has changed out of all recognition, I believe that Childe got the story pretty much right.
[24] Darwin 1871: 51; Childe1942: 14; Bruner 2021: 89.
[25] Klein 2009 is the best overview of human evolution, with Leakey's finds and their evolutionary implications on pp. 215-18 and 271-73. McNutt et al. 2021 report the latest footprints. Some geologists think that footprints at Trachilos on Crete indicate bipedal apes 6 million years ago (Gierlinski 2017), but there some questions remain (Meldrum and Sarmiento 2018; Kirscher et al. 2021.
[26] Profitt et al. 2016; Harmand et al. 2015; McPherron et al. 2010.
[27] Domínguez-Rodrigo et al. 2021; Aiello and Wells 2002; fig. 7 from Klein 2009: 728.
[28] Zhu et al. 2018; Klein 2009: 234-78; Braun et al. 2019; Collard and Wood 2015.
[29] Klein 2009: 282-306, 321-30; Ben-Dor et al. 2011; Pontzer 2012; Wrangham 2009.
[30] Klein 2009: 373-92; Stout et al. 2014; Wilkins et al. 2012; Domínguez-Rodrigo and Cobo-Sanchez 2017, compared with Rose and Marshall 1996; Häusler et al. 2013; Joordens et al. 2014; Morwood 2010; Barham and Everett 2020.
[31] Schiess et al. 2016; Tomasello et al. 1993: 495.
[32] Scott and Hosfield 2021; Shimelmitz et al. 2014.
[33] Lycett and Eren 2013; Zaidner et al. 2021.
[34] Brooks et al. 2018.
[35] Hublin et al. 2017; Pinson et al. 2022; Wrangham 2019; Adler et al. 2014; Higham 2021: 34-44.
[36] Klein and Edgar 2002 is the best account of the anatomically modern/behaviorally modern distinction.
[37] Enard et al. 2002; Krause et al. 2007; Atkinson et al. 2018; McBrearty and Brooks 2000; Shea 2011.
[38] Shennan 2001; Powell et al. 2009; C. Jones 2022; Henrich 2004.
[39] R. Jones 1977; Hiscock 2008: 136-44. Henrich 2004; Boyd et al. 2011.
[40] Li and Durbin 2011; Gibbons 2021; Reich 2018: 77-93; Higham 2021: 129-47; Sun et al. 2021; Bennett et al. 2021.
[41] Powell et al. 2009: 1298.
[42] Soffer 1989; Soffer et al. 1997; Svoboda 2020; Reverdin 2020; Klein 2009: 665-83. Quotation from p. 681.
[43] Stiner 2001; Zeder 2012; Janz 2016; Mueller 2022; Snir et al. 2015(although Weide et al. 2021 dispute the identification of at least some of the proto-weeds).
[44] Zohary et al. 2012.
[45] Richerson et al. 2001.
[46] Asouti and Fuller 2013; Scott 2009: 64-97, 178-217; quotation from 2017: 129.
[47] Bogaard 2005; Halstead 2014; Gaastra 2018; Kamjan 2022.
[48] Sherratt 1981; Marciniak 2011; Schmandt-Besserat 1997. Of all the accounts of early Egyptian kingship, Kemp 1989 remains the best.
[49] On the archaeological details, the papers in Renfrew and Scarre 2015 are excellent. On inequality, Kohler et al. 2017, Kohler and Smith 2018, Bogaard et al. 2019, and Fochesato et al. 2019 are essential reading.
[50] Morris et al. 2007; Morris 2004; Ober 2015.
[51] Morris 2010: 280-330; quotation from Harper 2017: 7. On Roman and Chinese structures, Scheidel 2015, and on the Roman Empire's declining utility for local elites, Tainter 1988.
[52] The literature on all these topics is immense. I describe my own views in much more detail in Morris 2010: 215-26, 331-520.
[53] Morris 2015: 56-57, 114-15. Scheidel 2010 and Ober 2019 are essential reading on ancient incomes.

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