2
Standing on the Shoulders of Giants: Collective Learning as a Key Concept in Big History

David Baker

Abstract

One of the key concepts for the human part of the grand narrative is known as 'collective learning'. It is a very prominent broad trend that sweeps across all human history. Collective learning to a certain degree distinguishes us as a species; it got us out of Africa and the foraging lifestyle of the Palaeolithic, and underpinned demographic cycles and human progress for over 250,000 years. The present article looks at collective learning as a concept, its evolution within hominine species, as well as its role in human demography and the two great revolutions in human history: agriculture and industry. The paper then goes on to explain the connection of collective learning to Jared Diamond's 'Tasmanian Effect'. Collective learning also played a key role in the two 'Great Divergences' of the past two thousand years. One is industry and the rise of the West, described to great effect by Kenneth Pommeranz, the other is the less well known: the burst of demography and innovation in Song China at the turn of the second millennium AD. Finally, the paper concludes with insights into how collective learning forges a strong connection between human history and cosmology, geology, and biology, through what is widely recognized as one of the 'unifying themes' of Big History – the rise of complexity in the Universe.

Keywords: *complexity, collective learning, demographic cycles, evolution, accumulation.*

When I arrived in Sydney in 2010 to start my PhD in Big History, my original topic was long-term patterns in Malthusian cycles. However, it was only a few weeks before I noticed the strong connection between population dynamics, the rise of complexity that is central to Big History's grand narrative, and a concept known as cultural evolution, which is the transmission of cultural ideas, beliefs, and attitudes through an algorithm of variation and selection very similar to the evolution of genes in biology. Cultural ideas evolve and adapt far faster than genetics and this permits a much more rapid increase in complexity. Cultural evolution is, of course, one of many manifestations of the

'Darwinian algorithm' that is observed in cosmology, geology, biology, and even quantum physics, that seems to play a role in rising complexity (Baker 2011a, 2013, 2014; Christian in this volume). My dissertation has explored the Darwinian connection among these differing physical processes and I have explored them in a few other articles, but in this article I would like to focus on an aspect of cultural evolution that is crucial to human progress and the upper end of the immense complexity the Universe has generated so far.

Collective learning is an ability to accumulate more innovation with each passing generation than is lost by the next. It has allowed humans to exploit our ecological niches with increasing efficiency and allowed us to largely harness the energy flows of the planet and the Sun. Through foraging, agriculture, and heavy industry collective learning has raised the carrying capacity of the population, allowing for more potential innovators, who in turn raise the carrying capacity, thus creating even more innovation. Gradually, over 250,000 years of humanity, the population has risen and we have generated increasingly complex societies and have developed the capacity to harness an enormous amount of energy. In terms of the wider rise of complexity and in processes of Universal Darwinism, collective learning is the summit of the process, and I say the next two words with emphasis, *thus far*.

The historian's view of all human history is no longer vague or boundless with a chaotic tangle of periods and research areas. Collective learning gives a clear and definite shape to the whole picture as well as an underlying theme. This is revolutionary not only for Big History, but for areas of conventional human history as well. The idea has its uses within archaeology, agrarian history, and within the study of the industrial era – not to mention our anxiety-fraught examination of the looming trials of the twenty-first century. For the concept of collective learning we are deeply indebted to David Christian for expounding it in his own works, and also anthropologists like Peter Richerson, Robert Bettinger, Michelle Kline, and Robert Boyd, for developing it mathematically and, in one case of a recent paper to the Royal Society, with a strong degree of empiricism (Christian 2005: 146–148; Richerson, Boyd, and Bettinger 2009: 211–235; Kline and Boyd 2010: 2559–2564).

In natural ecology, all organisms are slaves to some form of *S*-curve that restricts the amount of resources available to an individual and a species, enabling them to survive and reproduce. When the carrying capacity of a biological population is reached, the population undergoes strain, decline, and recovery. While potentially destructive to life-forms, it does have the merit of spurring along evolution by natural selection. Thomas Malthus' *Essay on the Principle of Population* (1798) illustrated how the human population growth always tended to exceed the resources capable of supporting its burgeoning numbers. Darwin read it in 1838 and extrapolated it to other organisms whereby species overbreed, compete, and change over time to possess the traits that are best able to extract resources from their environment and perpetuate their survival. It was an epiphany for him. At last, he said, 'I have finally got a theory with which to work' (Darwin 1887: 82). It also applies to human history. In his recent book, big historian Fred Spier identifies the unifying theme of our long story:

> If we want to prevent our bodily complexity as well as all the complexity that we have created from descending into chaos, we must keep harvesting matter and energy flows on a regular basis. *This is the bottom line of human history*. I will therefore argue that during most, if not all, of human history, the quest for sufficient matter and energy to survive and reproduce... has been the overriding theme (Spier 2010: 116; emphasis added).

Until a few million years ago there was nothing on Earth to indicate that anything else besides the *mêlée* of genetic evolution, with its constant generation and annihilation of diversity, would arise. It appeared the short, ignorant, and terrifying existence of beasts of the field was the highest level of complexity of which the planet was capable. Biology seemed like the finest manifestation of the Darwinian algorithm that gradually produced more and more complexity, with the annihilation of useful DNA mutations and the selection of useful ones. However, like stellar evolution builds on quantum Darwinism, like mineral evolution is an extension of stellar evolution, biological evolution soon spawned another Darwinian process. There emerged the groundswell of collective learning, the concept that a species' learning accumulates in ways over several generations that enhances their ability for survival. If harvesting energy to maintain our complexity is the bottom line of human history, then collective learning and its ability to raise the carrying capacity is without question the shape. That shape looks something like this.

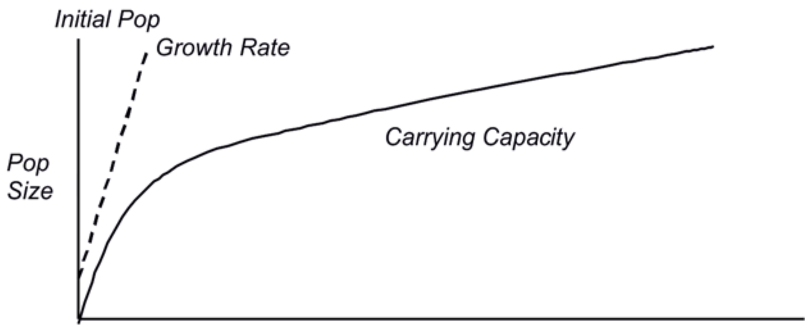

Fig. 1.

Source: Richerson *et al.* 2009: 219.

I. Collective Learning in the Palaeolithic

What precise ability enables collective learning? How did it evolve? What selection pressures made it spring into being? This engages with a much larger and much older debate over the nature of human uniqueness – something to which a refined version of collective learning can contribute. These ideas are universal grammar *à la* Noam Chomsky *vs.* symbolic reference *à la* Terrence Deacon, the emergent thought *vs.* the computational model of the mind, the role of imitation and mimicry in the evolution of language, and the debate over group selection in humans that raged over a recent book by Edward O. Wilson and the counterblast of Steven Pinker (Wilson 2012; Pinker 2012). While the importance of collective learning and technological accumulation to human history has been clearly identified, it is much less clear what trait or a set of traits enabled it in the first place. A number of theories exist and they all seem to revolve around the gradual and the sudden. Chomsky argues against gradualism and considers universal grammar an all or nothing proposition that somehow flickered into being (Chomsky 2002: 80). Pinker argues for a more gradual evolution of a computational model of the mind similar to the evolution of the eyes (Pinker 1997: 21). Deacon argues for the appearance of symbolic reference as a sudden occurrence (Deacon 1997: 328–355). Dunbar claims that enhanced communication abilities and technological accumulation were the gradual result of selection pressures on complex interaction and coordination due to increasing group size and inter-group connectivity (Dunbar 1996: 3–17, 56–58, 62–64, 77; 2004: 28–29, 71–72, 125–126; 2010: 22–33). Finally, Corballis places gesticulation as the fundamental form of social learning with speech being the ultimate form – thus being a change of degree and not of kind (Corballis 2002: 41–65). Whatever the skill that allowed humans to accumulate more innovation with one generation than was lost by the next, it needs to have a clear explanation about how it evolved in real terms without recourse to metaphor and with identifiable selection pressures – whether sudden or gradual.

These questions tie into the next issue: the threshold after which collective learning became possible. Where is it drawn? Is it the result of a gradual evolution over several species or a sudden jump? If we knew what ability, origin, and selection pressures caused collective learning, we might be able to better answer that question. For now it is a big blank spot on the map. Do we draw the line at humans? And if so, how do we treat the nascent elements of collective learning in our evolutionary family? David Christian often gives the example of the Pumphouse Gang baboons, where a skilled hunter dies and information eventually degrades, vanishes, and the range of the species does not expand. He also gives a nod to what he calls the 'sporadic learning' in apes and in *Homo habilis* and *Homo ergaster/erectus* (Christian 2005: 146). But if we place the threshold where more knowledge is accumulated with each generation than is lost by the next, we are confronted with questions about the significance of situations where knowledge neither degrades nor accumulates – it is simply preserved. For example, termite fishing, rock hammers, leaf sponges, branch levers, and banana leaf umbrellas are passed on by social learning, not instinct, and not sporadically, in certain populations of chimpanzees, and are withheld from others outside that cultural network (Pinker 1997: 198–199). They are sustained and passed on, usually from mother to offspring, and are not reinvented every generation. Here is a tremendous ability, however weak, probably possessed by our last common ancestor. This ought to tell us something about the nascent elements of collective learning. But, on the other hand, if this learning does not accumulate, but is only preserved, perhaps, it can conceivably be dismissed, if we wish to maintain a sudden threshold with humanity and not a gradualist account.

Similarly, the stagnant nature of stone tools 2.6–1.8 million years ago may potentially be dismissed as a 'sporadic learning', simply preserving knowledge but not accumulating it. Around 1.8 million years ago, however, the assertion grows more tenuous. Stone tool manufacture is less haphazard, with deliberate shapes being constructed that are passed on culturally. *Homo ergaster/erectus* also migrated into different environments in Asia, no mean feat, and there is evidence of a demographic boom in Africa that may have driven the migration. A demographic boom also indicates an enhanced ability to exploit niches in the ecosystem. There is also evidence of increased brain size and sociality (Stringer 2011: 25–26; Tattersall 2012: 123–124). All of these things are staple arguments for collective learning in *Homo sapiens* and the profound impact they had on the Palaeolithic world. There is no reason why the same arguments could not apply to *Homo ergaster/erectus*, albeit on a lesser scale. But this is a difference of scale, not a difference of kind.

Nevertheless, the jury is still out on whether there was any technological accumulation. When *Homo ergaster/erectus* first arrived on the scene 1.8 million years ago, they were making tools that had not changed significantly since *Homo habilis*. However, 1.78 million years ago we begin to observe rare and crude new forms of teardrop hand-axes in Kenya (Tattersall 2012: 105). But for about 200,000 years we see, for the most part, no major widespread improvements in the stone tools of *Homo ergaster/erectus*. This remained the case in most migratory regions. The tools were functional. The object was to get a flake edge. No aesthetics were involved. But in Africa 1.5 million years ago, where *Homo ergaster* populations were at their densest, the hand-axes first made 1.78 million years ago rapidly became common. What is more, they improve in quality, shaped with a flat edge into multipurpose picks, cleavers, and other kinds of implements (Tattersall 2008: 125–127). This has been considered by some archaeologists as the first clear sign of tinkering, accumulation, and improvement of technology, if only a much weaker form of collective learning among *Homo ergaster/erectus* than *Homo sapiens*, who are the real champions at it.

Still, the assertion that *Homo ergaster/erectus* had crossed the threshold into mild collective learning can still be reasonably disputed and dismissed if the case is only based on such limited evidence. This argument is less feasible for the hominines of the last million years. *Homo antecessor*, *Homo heidelbergensis*, and the Neanderthals presided over the systematised and regular use of fire in hearths (790,000 years ago), the earliest wooden spears (400,000 years ago), the earliest use of composite tools (400,000 years ago), the first evidence of intricately constructed shelters (350–400,000 years ago), and the first prepared core tools (300,000 years ago) all before *Homo sapiens* was ever heard of (Goren-Inbar *et al.* 2004: 725–727; Tattersall 2008: 125). *Homo heidelbergensis* became the first pan-Old World hominine (600,000 years ago), showing signs of technological improvement, with the earliest specimens using simpler tools than later ones, and even evidence of pigments at Terra Amata, a site in Europe 350,000 years ago (Oakley 1981: 205–211). The Neanderthals adapted to climes that made clothing and other cultural innovations necessary for insulation and warmth. There is also limited evidence for use of pigments (Stringer 2011: 163–165). They used complex tool manufacture, with prepared stone cores, producing a variety of implements, sharp points, scrapers, teardrop hand-axes, wood handles, with deliberate use of good stone materials, and an endless supply of variations and signs of improvement over time (Tattersall 2012: 166–173; 2008: 150–158).

Now, bearing in mind that *Homo sapiens*, without question, is by far the most talented at collective learning, there is very little doubt that these hominine innovations accumulated over several generations, did not fade away, improved in quality down the chronology, and yielded a certain degree of ecological success and extensification into new environments. Interestingly enough this happened in several hominine species for which there has yet to be found clear evidence of symbolic thought and complex language, two things that are sometimes (and probably incorrectly) attributed as the *cause* of collective learning rather than more efficient vehicles for it. All this raises severe questions about the threshold that must be addressed. It also bleeds into questions about human uniqueness and why it is so important for some people to draw an iron-clad boundary between us and our evolutionary family that distinguishes us in essential kind. This sort of essentialism is alien to many forms of evolution. It would be a rash statement indeed to say that if *Homo sapiens* had never existed and had never out-competed other hominines, that these same hominines would not have possessed collective learning or attained some degree of cultural complexity. Much more work, at any rate, would be required before one could make such a statement. As it is, it appears a more gradual evolution of collective learning occurred over several hominine species.

The question of a 'Palaeolithic revolution' is another point of contention. Did *Homo sapiens* undergo a biological change *c.* 50,000 years ago and does this explain the explosion of technological complexity that appears in the fossil record? Or did collective learning and population density achieve a point of saturation allowing for a faster pace of learning? Or did this complexity arrive in Africa prior to 100,000 years ago as McBrearty and Brooks have suggested (McBrearty and Brooks 2000: 453–563)? If the latter, it is probably the result of collective learning maintaining a faster rate of accumulation in denser African populations than disparate migrant ones. Collective learning may have also played a role in the Out-of-Africa migrations themselves. Recent DNA studies have shown exponential human population growth in Africa preceded our most successful migration out of that continent *c.* 60,000 years ago (Atkinson, Gray, and Drummond 2009: 367–373). This coincides with evidence of an increase in the complexity of technology around the same time (Mellars 2006: 9381–9386). It is possible that there is a correlation between migration and population growth that may be explained by the gradual rise of collective learning. If such a connection exists for the ecological success of humans, it might also be applied to the prior migrations of *Homo ergaster/erectus*, *Homo heidelbergensis*, and the Neanderthals. The human correlation is also reinforced by genetic studies by Powell, Thomas, and Shennan that show population density in Africa may have reached a critical mass to allow more consistent technological accumulation without as many periods of loss (Powell, Shennan, and Thomas 2009: 1298–1301).

Decline in population and collective learning can also lead to a Tasmanian Effect, where technology disappears or undergoes simplification. Jared Diamond coined the term for the extreme disappearance of technology in Tasmania (Diamond 1978: 185–186). Kline and Boyd recently established a similar case in Oceania, where technology declined in groups that were isolated or lost density (Kline and Boyd 2010: 2559–2564). My own work has unearthed a similar occurrence of technological disappearance and simplification in the extreme and sustained population decline of isolated parts of post-Roman Western Europe in the fifth and sixth centuries (Baker 2011b: 217–251). Finally, Zenobia Jacobs, Bert Roberts, Hilary Deacon, and Lyn Wadley established two Palaeolithic Tasmanian Effects in Africa, at Still Bay 72,000 years ago and Howieson's Poort 64,000 years ago (Jacobs *et al.* 2008: 733–735; Wadley *et al.* 2009: 9590–9594). All are cases where technology disappears or is simplified in areas that suffered isolation and population decline – a phenomenon deemed more likely in the Palaeolithic due to lower populations and lower connectivity. It might explain why collective learning took tens of thousands of years to get off the ground, relatively speaking, before the explosion of agriculture.

II. Accumulation of Innovations from Foraging to Agriculture

Culture evolves through an accumulation of small variations. Those ideas that are successful or useful, in whatever way, are selected and spread throughout a society. Every invention of technology or breakthrough in practice, like in agriculture, comes from a series of small improvements contributed by a long dynasty of innovators. The single innovation of a genius might be of revolutionary magnitude and repercussions, but would have been impossible without the hundreds of tiny innovations made by the hundreds of generations that came before it. Newton said he stood on the shoulders of giants. It might be fairer to say that every ordinary person stands on the shoulders of other ordinary people – some with more than ordinary perceptiveness and absolutely extraordinary timing. Our technologies, our institutions, our languages are far too elaborate for even the most gifted of geniuses to create from scratch. Human beings have a tremendous capacity for language. We can share information with great precision, accumulating a pool of knowledge that all people may use. The knowledge an individual contributes to that pool can long survive his death. If our populations are large and well-connected enough, more information is acquired by each passing generation than is lost by the next. It can be accessed and improved by countless generations.

From the origins of collective learning in the Palaeolithic, it is clear that from the rising carrying capacity and increase in cultural variants and innovations, that collective learning has great bearing on the historical narratives. Nowhere is this more relevant than the discussion of population cycles. The inception of the current arc of complexity is easily spotted. Around 74,000 years ago there was a catastrophic eruption at mount Toba, on the island of Sumatra, part of what is now Indonesia. It was worse than anything in recorded history. The eruption drastically lowered temperatures on Earth for several years (Rampino and Self 1992: 50–52). Genetic studies show that the resultant decline in flora and fauna upon which humans could predate had reduced the population to near extinction. It is likely that in the aftermath of a period of starvation, on the entire face of the Earth there were scarcely more than 10,000 (and perhaps as few as 1000) human souls, which, as an aside, is what makes our long history of racism so abhorrent and absurd, particularly those ideological impulses inspired by Darwinism (Williams *et al.* 2009: 295–314; Rampino and Ambrose 2000: 78–80; Ambrose 1998: 623–651). Here is a low watermark for the current trend of human population dynamics. Evidently the starvation did not last long. In approximately the same amount of time that separates us from the dawn of agriculture, the human species had recovered and *c.* 60,000 years ago migrated out of Africa across the world. By 30,000 years ago, the foraging human population had risen to half a million. By 10,000 years ago, the innovation of hunter-gatherer bands had allowed them access to almost every environment on Earth, from Eurasia to Australia to the Americas. We must remember that the carrying capacity for a foraging band is quite low and they need a vast area to supply relatively small numbers. Nevertheless, by the dawn of agriculture the ranks of our species had swelled to six million people, approaching the full capacity for supporting hunter-gatherers of which the entire surface of the Earth is capable (Livi-Bacci 1992: 31). Innovations began to mount up. The earliest recorded evidence for herding goats and sheep in Southwest Asia is from 11–12,000 years ago, and one thousand years later, we have evidence for the farming of wheat, barley, emmer, lentils, and pigs. By 8,000 years ago, East Asia had begun using millets and gourds, and the Americas had domesticated llamas and maize. By 6,000 years ago, Southwest Asia had domesticated dates and the grapevine, while East Asia had domesticated water chestnuts, mulberries, water buffalo, and that mainstay of all Asian crops – rice (Roberts 1998: 136). All of a sudden, much larger numbers could be supported over a much smaller land area. The agrarian civilizations brought about a greater degree of connectivity, faster population growth, and a new rapid pace for innovation. Suddenly there were a lot more minds to generate ideas and a lot less space between those minds in order to conference. Agricultural efficiency gradually improved and practices slowly spread to new regions. From the upper limits of the carrying capacity for foragers, the population increased nearly tenfold by 3000 BC to 50 million people, and it took only another 2000 years to increase this number to 120 million (Biraben 1979: 13–25). But there was a problem. The tinkering of ideas in cultural evolution is random, after all. For nearly 10,000 years, the growth in the carrying capacity of agriculture was sluggish while population growth was exponential, and so there was a series of miniature waves of population collapse and recovery throughout the period of agrarian civilizations. From there came the advent of industry which has raised the carrying capacity and enhanced collective learning by leaps and bounds.

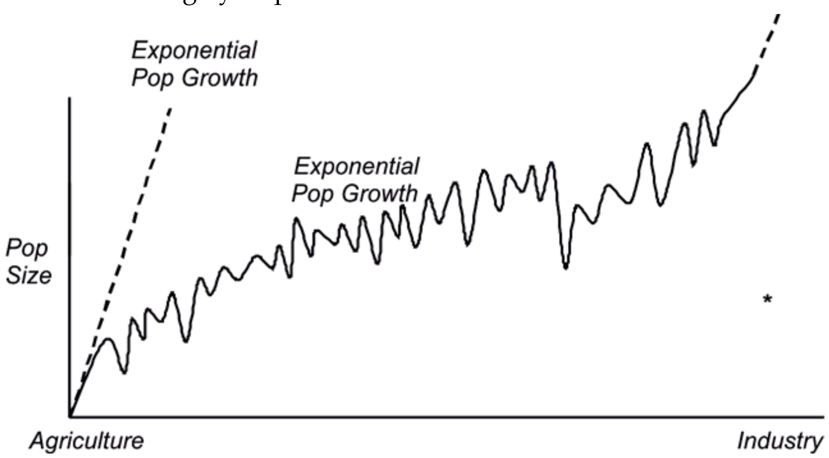

Fig. 2. The asterisk (*) marks a period of severe population decline where collective learning is lost

Bear in mind that each innocuous-looking downturn on the graph represents a period of intense starvation, suffering, and death. Every few centuries an agrarian civilization overshot its carrying capacity and countless famines, instability, poverty, and plagues ravaging a malnourished landscape, resulted. Each droop of the line represents the death of millions. Sometimes population loss would be so significant that it adversely affected the onward march of collective learning, as the asterisk simulates. If collective learning is lost, the carrying capacity falls, and the smaller group of innovators has to make up lost ground. This reversal of the process is known as the Tasmanian Effect.

III. Collective Learning Undermined and Overthrown

When a catastrophe strikes and a population is reduced and isolated, the accumulation of knowledge slows down and a population's ability to retain information is weakened. The most extreme example of this is from Tasmania, which possessed many technologies shared by their Australian relatives to the north, but whose skills and technologies gradually disappeared after Tasmania was cut off from Australia *c.* 10,000 years ago. Jared Diamond famously observed that when the Europeans first visited Tasmania in the seventeenth century, the native population was small, isolated, and lacked many of the tools and methods that the aboriginal Australians on the mainland possessed. The Tasmanians could not produce fire in hearths, they did not have boomerangs, shields, spears, no bone tools, no specialized stone tools, no compound tools like an axe head mounted on a handle, no woodworking, no sewing of clothes despite Tasmania's cold weather, and even though they lived on the sea coast, they had no technology for catching and eating fish (Diamond 1978: 185–186). Diamond hypothesized that this was caused by the loss of the land bridge between Australia and Tasmania *c.* 10,000 years ago. A subsequent recent study of Tasmania's archaeological and ethnohistorical evidence has borne out the same result (Henrich 2004: 197–218). The Tasmanians upon European contact had lost a great deal of technology that was enjoyed not only by their neighbours across the Bass Strait but also by most groups of *Homo sapiens* in the Palaeolithic. Humans probably arrived in Tasmania from Australia 34,000 years ago, across a land bridge, and were indeed cut off 12,000–10,000 years ago by the rising sea (Jones 1995: 423–446). The archaeological evidence shows that at the time of migration, the Tasmanians were producing bone tools, cold-weather clothing, fishhooks, hafted tools, fishing spears, barbed spears, fish/eel traps, nets, and boomerangs, and continued to do so even after the island was cut off by the rising seas. These tools gradually declined in frequency, variety, and quality between 8,000 and 3,000 years ago before completely disappearing from the archaeological record (Henrich 2004: 198). Thereafter, to hunt and fight, the Tasmanians used one-piece spears, rocks, and throwing clubs, and their entire toolkit consisted of 24 items, as opposed to the hundreds of tools possess by the Australians to the north (Ryan 1981). Bone tools are on the Tasmanian record from at least 18,000 years ago, just as they were in Australian records and also enjoyed by Palaeolithic man in Africa from 89,000 years ago (Webb and Allen 1990: 75–78). The archaeological record also shows that from 8,000–5,000 years ago, the Tasmanians relied heavily on fishing, second in their diet only to seal hunting, and much more than hunting wallabies. By 3,800 years ago, fish bones disappear from archaeological sites and it was not part of the Tasmanian diet when Europeans arrived (Henrich 2004: 199). All told, Jared Diamond's hypothesis forty years ago about a loss of knowledge due to connectivity and a shrinking population has been largely borne out by subsequent research.

It is not the only case where such a phenomenon has occurred, though it is undoubtedly one of the most extreme. Other Pacific groups have a history of losing canoe, pottery, and bow technology (Rivers 1926). The Inuit were decimated by a plague and lost knowledge to construct kayaks, bows and arrows, and the leister, until it was reintroduced by migrants from Baffin Island (Rasmussen 1908; Golden 2006). Michelle Kline and Robert Boyd detected a similar trend in Oceania (Kline and Boyd 2010: 2559–2564). The ecological similarity between these environments allowed Kline and Boyd to focus on fishing technology, preventing geographical differences from distorting the results. The groups also had a common cultural descent. The finding was that the number of tools and the complexity of them are higher in larger well-connected populations. Zenobia Jacobs, Bert Roberts, Hilary Deacon, and Lyn Wadley have determined that there was a Tasmanian Effect at Still Bay 72,000 years ago and Howieson's Poort 64,000 years ago (Jacobs *et al.* 2008: 733–735; Wadley *et al.* 2009: 9590–9594). At Still Bay, humans created highly complex flake technology, including finely shaped, bifactually worked spearheads. At Howieson's Poort, humans created composite weapons and stone artifacts, both of which were hafted. These two sites were more innovative than much else in Middle Stone Age Africa, and an increasingly complex social organization is implied by the use of bone tools, symbols, and personal ornaments. The strange thing is that these two industrious cultures are separated by several thousand years of stagnation and total disappearance of their technologies. And the differences between the way the technologies of Still Bay and Howieson's Poort are constructed implies that when Still Bay disappeared, the innovators of Howieson's Poort started from scratch.

Both cultures intriguingly fall within the genetic bottleneck that occurred 80–60,000 years ago (Jacobs *et al.* 2008: 733). It would appear a relatively low carrying capacity for hunter-gatherers ranging across a territory, the small size of their groups, and their vulnerability to ecological changes and disasters made the disappearance of knowledge more common in the Palaeolithic. The Tasmanian Effect is not just confined to hunter-gatherer societies, however, though due to the low connectivity and small populations of those societies it may be more common. The Tasmanian Effect can also occur in agrarian civilizations. It occurred in the post-Roman West in the fourth, fifth and sixth centuries AD. We must make clear, however, that this trend was not mirrored in the Roman-Byzantine East, which underwent a different population trend, including growth through the fourth, fifth, and into the sixth centuries AD. The extreme settlement abandonment of the Roman West, started in 350, intensified by the Germanic invasions, and then further exacerbated by the bubonic plague of Justinian, reduced the already sparse and illiterate population to low levels. The loss of technology and expertise is reflected in the decline of various artisanal practices, pottery methods, military equipment and architectural knowledge (Murray-Driel 2001: 56–64; Pugsley 2001: 112–115; Ward-Perkins 1999: 227–232; Arthur 2007: 181; Mannoni 2007: xlv-xlvii; Knight 2007: 100; Rossiter 2007: 115; Bishop and Coulston 1993: 122–149; Coulston 2002: 23; Williams 2002: 45–49; Murray 1986: 31–32; King 2001: 26–28). It remained to subsequent generations to rediscover classical learning and devise new methods to make up for this shortfall and raise the carrying capacity once again. The process of recovery from the Tasmanian Effect took Western Europe more than 700 years.

IV. Song China and Industrial Britain: The Two 'Great Divergences'

In the past two millennia, certain key innovations in Song China and Industrial Britain have prompted an explosion of growth in collective learning, bringing humanity ever closer to industrialization. There were other periods in human history which arguably could be deemed as 'explosions' of collective learning (the Axial Age, the Renaissance, the Enlightenment, the Scientific Revolution, *etc.*) but what is notable about Song China and Industrial Britain is that they were explosions in collective learning that prompted one world zone to tear ahead of their contemporaries in that time period. Hence, scholars often use the phrase 'great divergence' as popularised by Ken Pomeranz (2000). This term has so far applied to the industrial divergence that separated 'West from rest', but taken within the context of collective learning it can also apply to an earlier period.

The first great divergence was in Song China in the ninth and tenth centuries AD which led to something staggeringly similar to the rates of innovation and production seen in the Industrial Revolution. In the sixth century BC, the carrying capacity of China was already ahead of ancient Europe. China was already growing crops in rows, paying attention to weeding, and frequently employing iron ploughs. All of these innovations would not be employed in Europe for centuries. The Chinese also used horse harnesses by the third century BC, avoiding the risk of strangulation by a horse and permitting them to carry ploughs and heavy equipment. The seed drill came into use by the second century BC. In the first-second century BC, the types of mouldboard ploughs that only became available in Europe after Charlemagne were already in use in China (Temple 1986: 15–20). At the time, the majority of the Chinese population concentrated in the north in the Yellow River valley where they farmed millet and wheat – not rice (Ponting 1991: 93). Even before the explosion of wet rice agriculture in China, these innovations served to create a higher agricultural output and carrying capacity compared with Roman Europe centred on the Mediterranean Sea, both in the East and especially the sparsely populated backwater that was the Roman West.

Until the first millennium AD, both world zones had supported themselves mainly on grain products, with the Chinese sustaining a higher carrying capacity than Europe due to better agricultural practices. Even further divergence happened between 500 and 1000 AD with the spread of wet rice production in China, which has a much higher yield than grain. Per hectare, traditional varieties of rice support around 5.63 people compared to 3.67 people on a hectare of wheat (Fernandez-Armesto 2001: 105). Dry rice farming came first. However, it has a carrying capacity that is not much higher than wheat. The problem is that dry rice farming requires constant weeding (Woods and Woods 2000: 50). It was also ill-suited to the climate of northern China. In the north, millet farming in the Yellow River valley began in 6,000 BC (Higman 2012: 23). By 200 BC, the Han north was sustained by the farming of millet and wheat in an inefficient two-crop rotation. The inhospitable soils and temperatures of the Yellow River valley in the north usually permitted only one crop a year. From AD 1, wheat was immediately planted after millet or soy to increase crop frequency. In order to avoid too much loss of nutrients from repeated planting, the crop was often planted in alternating furrows, with new furrows being planted in between the old ones. The Han plough had limited depth of ploughing. Over-seeding was sometimes used to save labour at the expense of the yield (Hsu 1980: 112–114).

Meanwhile, in southern China, rice was domesticated in 7,000 BC along the Yangtze River and by 3,000 BC, a large-scale wet rice farming was present (Chi and Hung 2010: 11–25; Zheng *et al.* 2009: 2609–2616). For several thousand years, the yield was still relatively low because farmers did not employ terracing and paddy systems. Instead, wet rice was grown beside streams and in small irrigated plots (Simmons 1996: 99). This is the reason why northern China held the bulk of the population despite a long history of wet rice farming in the south. Nevertheless, wet rice farming even without terracing and paddies was fairly productive. In the third century BC, the Qin Emperor Shi Huangdi constructed a 20-mile canal to facilitate transport of wet rice from southern China to the populous north (Headrick 2009: 43). Slowly but surely the carrying capacity was being raised. Finally, labour intensive methods of terracing and paddies caught on in southern China in AD 200 (Chang 2003: 16). The employment of a crop with much higher yields than grain and that can sustain higher population densities, might go some way to explaining the higher rate of collective learning and innovation that set these civilizations ahead of other zones in Eurasia in terms of population and cultural complexity.

At the fall of the Han dynasty, the barbarian attacks forced more Chinese south to the Yangtze River basin. The reunification under the Sui in AD 589 made the region more stable, and rice expansion and the migration of the northern population to the south continued in earnest (Ponting 1991: 93). Gradually, migration between AD 500 and 1300 transformed the agricultural output and population distributions of China, particularly intensifying in the Song dynasty (AD 960–1276). The Song government initiated a set of policies to shift agricultural production from the northern millet and wheat regions to the wet rice producing south. In 1012, the Song introduced a strain of rice from Vietnam that allowed for multiple harvests per year, or the alternation of rice in summer and wheat in winter. The government appointed 'master farmers' from local communities, who were to disseminate new farming techniques and knowledge of new tools, fertilizers, and irrigation methods. The Song also introduced tax breaks on newly reclaimed land and low-interest loans for farmers to invest in new agricultural equipment and crops (Bray 1986: 203). The Song encouraged terracing, created fields that were evenly flooded and trapped fertile silts from being washed away. In 1273, the Chinese government distributed 3,000 copies of *Essentials of Agriculture and Sericulture* to landowners in order to improve crop yields. Wet rice farming by this method produced two-three crops a year compared to the meagre one-crop harvest of the millet-producing north (Headrick 2009: 51–52, 85).

The adoption of wet rice farming and the migration of many people to the south had a profound impact on collective learning in Song China. In AD 1, the population of China was around 50–60 million and did not exceed that number level until the tenth century (Faser and Rimas 2010: 118). During the 900s and 1000s under the Song dynasty, migration to the Yangzi river valley to farm rice raised the carrying capacity of China from 50–60 million to 110–120 million, with record high population densities of 5 million people farming an area of 40×50 miles (Korotayev, Malkov, and Khaltourina 2005: 186–188). By 1100, this constituted 30–40 per cent of the population of the globe, compared to all Europe's 10–12 per cent as it just entered its 'Great Leap Forward' (Biraben 1979: 16). The population was raised, so was the density, and so the number and connectivity between potential innovators was increased. This really constitutes the first 'Great Divergence' between East and West, when Chinese collective learning advanced by leaps and bounds by a much higher carrying capacity. It is no coincidence that the Song dynasty was one of the most technologically advanced and industrially prodigious societies in pre-modern history, almost to the point that the late Song dynasty could conceivably have had an Industrial Revolution of their own. For instance, the annual minting and use of coin currency was increased greatly under the Song (Hansen 2000: 264). Farming techniques improved: the use of manure became more frequent, new strains of seed were developed, hydraulic and irrigation techniques improved, and farms shifted to crop specialization (Elvin 1973: 88). Coal was used to manufacture iron and iron production increased from 19,000 metric tons per year under the Tang (AD 618–907) to 113,000 metric tons under the Song (Hansen 2000: 264). The Song dynasty was the first to invent and harness the power of gunpowder. Textile production showed the first ever signs of mechanization (Pacey 1990: 47). Some surprisingly modern innovations in Song China did not arise in conjunction with an increased population, but the eleventh and twelth century innovations followed after the initial rise of the Chinese carrying capacity between AD 500 and 1000. The adoption of wet rice farming and the migration of the Chinese farmers from the northern grain producing region to the Yangzi River valley triggered a rise in the number of potential innovators and a Great Divergence that placed China as one of the largest, densest, and most productive regions of the globe from AD 900 to 1700 – at the very least.

The second explosion of collective learning was the Industrial Revolution itself. It was born out of a collection of small innovations that were selected and spread, combining into a feedback effect that significantly increased the carrying capacity of the human species. In 1709, Abraham Darby used coke to manufacture iron, inefficiently, until tinkering made the practice efficient enough in the 1760s to be selected and spread across Britain. Henry Cort invented a process in 1784 to create bars of iron without use of coke, further increasing efficiency (McClellan and Dorn 1999: 279–281). In seventeenth century France, Denis Papin revived an invention that was known to the Romans, the Chinese, and many other cultures using atmospheric pressure, later worked on by Englishman Thomas Savery, and eventually producing Thomas Newcomen's steam engine in 1712. More tinkering and the harnessing of a steam engine to power a blast furnace for iron production in 1742 also raised production. From there James Watt tinkered with the steam engine in the 1760s making it even more efficient (*Ibid.*: 282). In textiles, the Dutch innovations using waterwheels and the Italian factory plans were brought into England and further innovated into textile production in the 1730s. Three more innovations in the 1780s – the waterframe, the spinning jenny, and the spinning mule, all built on these innovations – transformed cotton to a common commodity rather than a luxury good (Mokyr 1990: 96–98, 111). Once the steam engine was brought into these innovations, the production efficiency advanced even more. From here the steam engine was also brought in to enhance locomotion. The nineteenth century saw this advanced capacity for production and innovation spread into almost every industry and across Europe and the globe. Much of the initial practices that led to the spark of industry were familiar in medieval China, but it was these cultural variations that came together at the right time in the right place to raise the carrying capacity and produce a Cambrian explosion of further innovation (Pacey 1990: 113; Mokyr 1990: 84–85; Needham 1970: 202). In many ways, it was a matter of chance. The occurrence of variation and selection is the key to the advance of collective learning. Conditions have to be just right, there has to be an available niche, and certain cultural variations have to be able to combine to produce material breakthroughs.

V. Collective Learning and the Rise of Complexity

From here collective learning has delivered us to the increased amount of energy, production, and almost instantaneous connectivity that we enjoy today. We have split the atom, revealing for the first time a microcosm of the massive amounts of energy that have radiated for billions of years out from the heart of the sun. We have established highly efficient forms of mass transportation, by sea, land, and air. We have seen the birth and expansion of the Internet, which ties the entire globe of potential innovators together into one community of lightening fast communication. The world's population has just passed seven billion, providing us with an increasing number of potential innovators. Provided we do not exhaust the resources of the planet in the same way that agrarian civilizations occasionally exhausted the resources of the field, we may be facing another explosion of innovation quite soon that shall look as different from the technologies of the industrial and post-industrial eras as factories and assembly lines differ from the implements of early agriculture. Collective learning not only defines our past and present, but our future as well. From this source radiates greater and greater amounts of complexity.

It is important to look at how collective learning ties into the broader Big History themes developed by Eric Chaisson and Fred Spier: the rise of complexity in the Universe and energy flows. It would appear that collective learning plays a direct mechanistic role in increasing the level of free energy rate density and also the number of available cultural variations and technological innovations. This raises the level of complexity in the Universe, just as solar, chemical, and biological evolution do.

Collective learning and rising complexity also ties into Universal Darwinism, an algorithm of random variation and non-random selection, which I have explored in other works (Baker 2011a, 2013, 2014). Variations emerge from collective learning on an unprecedented scale. By comparison, few variations emerge from the chaos of the quantum realm to the Newtonian physical realm, only about a hundred elements emerge from stellar evolution, a few thousand variations emerge from chemical/mineral evolution, millions of variations emerge in the biological realm, and in cultural evolution and collective learning the many variations of innovation are increased further still.

At each stage the free energy rate density increases, as does the magnitude of energy that can be harnessed. And it would appear that the number of possible outcomes is relative to the complexity of the process under discussion. When we arrive at something as complex as culture and modern human society, with a free energy rate density that is many times higher than the average product of genetic evolution and four million times higher than a galaxy, there are a mind-boggling number of cultural and technological combinations. Essentially, if you were to take a human brain and a brain sized chunk of a star, there is no question that the former would have a much higher density of free energy at any given time. The rate of complexity seems to increase with the number of viable selection paths.

Table 1. Amount of free energy running through a gram per second, and the australopithecine and human free energy rate density is determined from the average energy consumption of an individual (Chaisson 2010: 28, 36)

Generic Structure	Average Free Energy Rate Density (erg/s/g)
Galaxies	0.5
Stars	2
Planets	75
Plants	900
Animals (*i.e.* human body)	20,000
Australopithecines	22,000
Hunter-Gatherers (*i.e.* 250,000–10,000 years ago)	40,000
Agriculturalists (*i.e.* 10,000–250 years ago)	100,000
Industrialists (*i.e.* 1800–1950)	500,000
Technologists (*i.e.* present)	2,000,000

It would appear, for the time being, that collective learning and the complexity it bestows is the highest point in this process of which we are yet aware. There are two tiers of human evolution. The first is genetics, which operates in the same way as for other organisms. Those genes gave humans a large capacity for imitation and communication. Those two things enabled the second tier. Culture operates under similar laws, but on a much faster scale. Cultural variations are subject to selection and the most beneficial variations are chosen. Unlike genes, these variations can be transmitted between populations of the same generation and can be modified numerous times *within* that generation. Like a highway overpass looming over older roads, collective learning can blaze along at a much faster rate of speed.

We do not yet know where this tremendous capacity for collective learning will lead. It is likely to reveal even higher levels of complexity in the future, if we do not wipe ourselves out. When it comes to the broader trend in the Universe, it is fairly clear that the next rise of complexity will be down to animate rather than inanimate physical processes. As stars burn down, as planetesimals tumble through cold space, it may be that species like us, with a tremendous ability for collective learning and harnessing energy flows, will reveal even more remarkable phases of cosmic evolution. In that sense, collective learning tells us not only about human history, but about the overwhelming thrust of human destiny in a rising crescendo of complexity. That is, if we do not go extinct beforehand. An asteroid collision, a volcanic super-eruption, or a nuclear war could wipe the slate clean. Eventually the Sun will destroy the Earth. Even in the short term, as the twenty-first century appears to deepen further into crisis, the entire arc of collective learning could come very abruptly to an end. We shall then never know where collective learning might have led us or what we might have achieved as a population of billions of increasingly educated and well connected innovators. Mankind's great task in the twenty-first century is to survive it.

References

Ambrose S. 1998. Late Pleistocene Human Population Bottlenecks, Volcanic Winter, and Differentiation of Modern Humans. *Journal of Human Evolution* 34: 623–651.

Arthur P. 2007. Form, Function, and Technology in Pottery Production from Late Antiquity to the Early Middle Ages. *Late Antique Archaeology: Technology in Transition, AD 300–650* / Ed. by L. Lavan, E. Zanini, and A. Sarantis, pp. 159–186. Leiden: Koninklijke Brill.

Atkinson Q., Gray R., and Drummond A. 2009. Bayesian Coalescent Inference of Major Human Mitochondrial DNA Haplogroup Expansions in Africa. *Proceedings of the Royal Society B* 276: 367–373.

Baker D. 2011a. On Human Evolution in History. *International Journal of Interdisciplinary Social Sciences* 6 (7): 51–62.

Baker D. 2011b. The Roman Dominate from the Perspective of Demographic-Structural Theory. *Cliodynamics* 2: 217–251.

Baker D. 2013. The Darwinian Algorithm and a Possible Candidate for a Unifying Theme of Big History. *Evolution*: *Development within Big History, Evolutionary and World-System Paradigms* / Ed. by L. Grinin, and A. Korotayev, pp. 235–248. Volgograd, Russia: Uchitel.

Baker D. 2014. 10500: The Darwinian Algorithm as a New Research Agenda in Big History. *From Big Bang to Global Civilisation: A Big History Anthology* / Ed. by B. Rodrigue, L. Grinin, A. Korotayev. London: Primus Books. In press.

Biraben J. R. 1979. Essai sur l'évolution du nombre des hommes. *Population* 34: 13–25.

Bishop M., and Coulston J. 1993. *Roman Military Equipment from the Punic Wars to the Fall of Rome*. London: B. T. Batsford.

Bray F. 1986. *The Rice Economies: Technology and Development in Asian Societies*. Oxford: Basil Blackwell.

Chaisson E. 2010. Energy Rate Density as a Complex Metric and Evolutionary Driver. *Wiley Periodicals* 16: 27–40.

Chang Te-Tzu. 2003. Origin, Domestication, and Diversification. *Rice: Origin, History, Technology, and Production* / Ed. by C. Smith and R. Dilday, pp. 3–26. London: John Wiley.

Chi Z., and Hung H. C. 2010. The Emergence of Agriculture in South China. *Antiquity* 84: 11–25.

Chomsky N. 2002. *On Nature and Language*. Cambridge: Cambridge University Press.

Christian D. 2005. *Maps of Time: An Introduction to Big History*. Berkeley, CA: University of California Press.

Corballis M. 2002. *From Hand to Mouth: The Origins of Language*. Princeton, NJ: Princeton University Press.

Coulston J. 2002. Arms and Armour of the Late Roman Army. *A Companion to Medieval Arms and Armour* / Ed. by D. Nicolle, pp. 3–24. Woodbridge: Boydell Press.

Darwin Ch. 1887. *The Autobiography of Charles Darwin* / Ed. by F. Darwin. London: John Murray.

Deacon T. 1997. *The Symbolic Species: The Co-Evolution of Language and the Brain*. New York: W.W. Norton.

Diamond J. 1978. The Longest Isolation, the Simplest Technology. *Nature* 273: 185–186.

Dunbar R. 1996. *Grooming, Gossip, and the Evolution of Language*. London: Faber and Faber.

Dunbar R. 2004. *The Human Story: A New History of Mankind's Evolution*. London: Faber and Faber.

Dunbar R. 2010. *How Many Friends Does One Person Need? Dunbar's Number and Other Evolutionary Quirks*. London: Faber and Faber.

Elvin M. 1973. *The Pattern of the Chinese Past*. Stanford: Stanford University Press.

Faser E, and Rimas A. 2010. *Empires of Food: Feast, Famine, and the Rise and Fall of Civilisations*. Berkeley, CA: Counterpoint.

Fernandez-Armesto F. 2001. *Food: A History*. London: Macmillan.

Golden H. 2006. *Kayaks of Greenland*. Portland: White House Press.

Goren-Inbar N., and Alperson N., Kislev M. E., Simchoni O., Melamed Y., Ben-Nun A., and Werker E. 2004. Evidence of Hominin Control of Fire at Gesher Benot Ya'aqov Israel. *Science* 304: 725–727.

Hansen V. 2000. *The Open Empire: A History of China to 1600*. New York: W. W. Norton.

Headrick D. 2009. *Technology: A World History*. Oxford: Oxford University Press.

Henrich J. 2004. Demography and Cultural Evolution: Why Adaptive Cultural Processes Produced Maladaptive Losses in Tasmania. *American Antiquity* 69: 197–218.

Higman B. 2012. *How Food Made History*. Chichester: Wiley Blackwell.

Hsu Cho-yun. 1980. *Han Agriculture: The Formation of Early Chinese Agrarian Economy, 206 BC – AD 220* / Ed. by J. Dull. Seattle, WA: University of Washington Press.

Jacobs Z., and Roberts R., Galbraith R., Deacon H., Grün R., Mackay A., Mitchell P., Vogelsang R., and Wadley L. 2008. Ages for the Middle Stone Age of Southern Africa: Implications for Human Behavior and Dispersal. *Science* 322 (5902): 733–735.

Jones R. 1995. Tasmanian Archaeology: Establishing the Sequence. *Annual Review of Anthropology* 24: 423–446.

Livi-Bacci M. 1992. *A Concise History of World Population.* Transl. by C. Ipsen. Oxford: Blackwell.

King R. 2001. *Brunelleschi's Dome: The Story of the Great Cathedral in Florence*. London: Pimlico.

Kline M., and Boyd R. 2010. Population Size Predicts Technological Complexity in Oceania. *Proceedings of the Royal Society* 277: 2559–2564.

Knight J. 2007. *The End of Antiquity: Archaeology, Society, and Religion AD 235–700.* 2nd ed. Stroud: Tempus.

Korotayev A., and Malkov A., and Khaltourina D. 2005. *Laws of History: Mathematical Modelling of Historical Macroprocesses*. Moscow: Komkniga.

Malthus Th. 1798. *An Essay on the Principle of Population, as it Affects the Future Improvement of Society with Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers.* London: Printed for J. Johnson, in St. Paul's Church-Yard.

Mannoni T. 2007. The Transmission of Craft Techniques According to the Principles of Material Culture: Continuity and Rupture. *Late Antique Archaeology: Technology in Transition, AD 300–650* / Ed. by L. Lavan, E. Zanini, and A. Sarantis. Leiden: Koninklijke Brill.

McBrearty S., and Brooks A. 2000. The Revolution that Wasn't: A New Interpretation of the Origin of Modern Human Behaviour. *Journal of Human Evolution* 39: 453–563.

McClellan J., and Dorn H. 1999. *Science and Technology in World History: An Introduction*. Baltimore: Johns Hopkins University Press.

Mellars P. 2006. Why Did Human Populations Disperse from Africa ca. 60,000 Years Ago? A New Model. *Proceedings of the National Academy of Sciences* 103: 9381–9386.

Mokyr J. 1990. *The Lever of Riches: Technological Creativity and Economic Progress*. Oxford: Oxford University Press.

Murray P. 1986. *The Architecture of the Italian Renaissance*. London: Thames and Hudson.

Murray-Driel C. van. 2001. Technology Transfer: The Introduction and Loss of Tanning Technology during the Roman Period. *L'artisanat Romain: évolutions, Continuités et Ruptures (Italie et provinces occidentals)* / Ed. by M. Polfer, Montagnac: Éditions Monique Mergoil.

Needham J. 1970. *Clerks and Craftsmen in China and the West*. Cambridge: Cambridge University Press.

Oakley K. 1981. Emergence of Higher Thought, 3.0–0.2 Ma B. P. *Philosophical Transactions of the Royal Society B* 292: 205–211.

Pacey A. 1990. *Technology in World Civilisation*. Cambridge: MIT Press.

Pinker S. 1997. *How the Mind Works*. London: Allen Lane.

Pinker S. 2012. The False Allure of Group Selection. (June 2012) Edge.org.

Pomeranz K. 2000. *The Great Divergence: China, Europe, and the Making of the Modern World Economy*. Princeton, NJ: Princeton University Press.

Ponting C. 1991. *A Green History of the World: The Environment and the Collapse of Great Civilisations*. London: Penguin.

Powell A., and Shennan S., Thomas M. 2009. Demography, Skill Accumulation, and the Origins of Behavioural Modernity. *Science* 324: 1298–1301.

Pugsley P. 2001. Trends in Roman Domestic Woodwork: Bright Ideas and Dead Ends. *L'artisanat romain: évolutions, continuités et ruptures (Italie et provinces occidentals)* / Ed. by M. Polfer, pp. 111–116. Montagnac: Éditions Monique Mergoil.

Rampino M., and Self S. 1992. Volcanic Winter and Accelerated Glaciation Following the Toba Super-Eruption. *Nature* 359: 50–52.

Rampino M., and Ambrose S. 2000. Volcanic Winter in the Garden of Eden: The Toba Super-Eruption and the Late Pleistocene Population Crash. *Volcanic Hazards and Disasters in Human Antiquity* / Ed. by F. McCoy, and W. Heiken, pp. 71–82. Boulder, CO: Geological Society of America.

Rasmussen K. 1908. *People of the Polar North*. London: Kegan, Paul, Trench, Trubner & Co.

Richerson P., Boyd, R., and Bettinger R. 2009. Cultural Innovations and Demographic Change. *Human Biology* 81: 211–235.

Rivers W. 1926. *Psychology and Ethnology*. New York: Harcourt, Brace & Co.

Roberts N. 1998. *The Holocene: An Environmental History*. Oxford: Blackwell.

Rossiter J. 2007. Wine-Making after Pliny: Viticulture and Farming Technology in Late Antique Italy. *Late Antique Archaeology: Technology in Transition, AD 300–650* / Ed. by L. Lavan, E. Zanini, and A. Sarantis, pp. 93–118. Leiden: Koninklijke Brill.

Ryan L. 1981. *The Aboriginal Australians*. London: Queensland University Press.

Simmons I. G. 1996. *Changing the Face of the Earth*. 2nd ed. London: Blackwell.

Spier F. 2010. *Big History and the Future of Humanity*. Chichester: Wiley-Blackwell.

Stringer Chris. 2011. *The Origin of Our Species*. London: Allen Lane.

Tattersall I. 2008. *The World from its Beginnings to 4000 BCE*. Oxford: Oxford University Press.

Tattersall I. 2012. *Masters of the Planet: Seeking the Origins of Human Singularity*. New York: Palgrave Macmillan.

Temple R. 1986. *The Genius of China: 3000 Years of Science, Discovery, and Invention.* New York: Touchstone.

Wadley L., Hodgskiss T., and Grant M. 2009. Implications for Complex Cognition from the Hafting of Tools with Compound Adhesives in the Middle Stone Age, South Africa. *Proceedings of the National Academy of Sciences* 106: 9590–9594.

Ward-Perkins B. 1999. Re-using the Architectural Legacy of the Past, Entre Idéologie et Pragmatisme. *The Idea and Ideal of the Town between Late Antiquity and the Early Middle Ages* / Ed. by G. Pietro Brogiolo, and B. Ward-Perkins, pp. 225–244. Leiden: Brill.

Webb C., and Allen J. 1990. A Functional Analysis of Pleistocene Bone Tools from Two Sites in Southwest Tasmania. *Archaeology in Oceania* 25: 75–78.

Williams A. 2002. The Metallurgy of Medieval Arms and Armour. *A Companion to Medieval Arms and Armour* / Ed. by D. Nicolle, pp. 45–54. Woodbridge: Boydell Press.

Williams M., Ambrose S., van der Kaars, S. *et al.* 2009. Environmental Impact of the 73 ka Toba Super-Eruption in South Asia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 284: 295–314.

Wilson. E. O. 2012. *The Social Conquest of the Earth*. London: Liveright Publishing.

Woods M. and Woods M. 2000. *Ancient Technology: Ancient Agriculture from Foraging to Farming.* Minneapolis, MN: Runestone Press.

Zheng Y., Sun G., Qin L., Li C., Wu X., Chen X. 2009. Rice Fields and Modes of Rice Cultivation between 5000 and 2500 BC in East China. *Journal of Archaeological Science* 36: 2609–2616.