[*Expositions* 8.1 (2014) 39–60] *Expositions* (online) ISSN: 1747–5376

An Introduction to Big History

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Big historians place the written record of the human past within the natural record of the entire past, beginning with the big bang almost 14 billion years ago. By drawing on the natural sciences, they have revolutionized the field of history that in academia has normally been placed within the humanities or social sciences. They have studied light, rocks, bones, and blood as well as written texts, and then rethought the narrative of time and the place of humans in it. They study nature to tell a story of the entire past from which humanity has emerged and remains embedded. This provides a context for understanding the present and options for exerting constructive influence in the future.

Historians often argue that we cannot understand where we are in the present without understanding where we came from in the past. Big historians have pushed back the traditional point for when the past is thought to have begun. The story of humanity does not begin with writing, it starts with the components that gradually, in fits and starts over a long time, gradually combine to form a good deal many things, including humans and our relationships.

By integrating the evidence discovered by the natural sciences, they present a series of time periods that lead us from the first origins of matter immediately after the big bang, to stars and galaxies about half a billion years later, the combination of atoms within molecules, minerals, and rocks in space, the formation of a second generation star like our sun just under 5 billion years ago, the accretion of Earth 4.5672 billion years ago, the first emergence of life about 3.8 billion years ago, increasingly complex life starting about a half billion years ago, the evolution of hominins just under 8 million years ago, the appearance of *Homo sapiens* about 200,000 years ago, and then key cultural developments such as collective learning, agriculture, industrialization and urbanization, and the digital age.

The big history approach challenges traditional history in content and method. Traditional historians have often labored in archives to read primary written sources, as well as in libraries to compare historiographical secondary sources. With this research, they have analyzed past centuries and millennia. Big historians add to that their study of the results from the natural scientists to include all that which eventually was combined within human society. Humanity did not emerge fully blown, but evolved out of very long complex processes that continue to influence who humans are today. We cannot understand humanity without understanding humanity's past and the pre-human past.

Not only does the work of big historians challenge their own discipline to redefine itself, it does the same for other disciplines in the liberal arts, including ethics, theology and religious studies, literature, political science, and others. The physical sciences and big history, sometimes also called "cosmic evolution," offer much to those who focus not only on time, but also culture, art, politics, and other human endeavors. In one way, this is nothing new. The famous ancient Greek philosopher Aristotle wrote books such as one on physics, another on politics, a third of ethics, and many others. In the *Politics*, he wrote that "man is by nature a political animal." In the European medieval period, Thomas Aquinas developed Aristotelian thought on natural law; he argued that humans were created within a politically constituted community. By the seventeenth and eighteenth centuries, such State of Nature political philosophers as Thomas Hobbes, John Locke, and Jean-Jacques Rousseau postulated human politics before or without such institutions as the state. They wanted to determine how to construct states so that they helped resolve the basic problems of human nature. For all of their differences, they all saw humans as rooted in nature. None of them had the same understanding of nature as has developed since Darwin, Einstein, Hubble, and others in the past couple centuries.

Big history and contemporary physical sciences lead us to new understandings of human nature within the rest of nature. The emergent complexity of sustained, structured relationships that incorporate earlier ones in new combinations and with new properties is possible due to access within pockets to high quality energy. The second law of thermodynamics would lead us to expect entropy, or transitions from greater to lesser order rather than emergent complexity. However, from the big bang to our current period of partial globalization, we can observe in certain places a process of increased complexity. If we can resolve our current energy crisis in a sustainable way, and if we have the imagination, this process may continue. However, there was no uniformity in emergent complexity in the past and there is no guarantee it will continue in the near future.

Baryonic Matter

Big history begins at the beginning of time with the first appearance of the elementary particles from which humans and all else are formed. If the big bang theory is correct, nothing turned into something 13.82 billion years ago, and began expanding from an infinitely hot and dense point without mass into our universe. It may be that nothing is always pulsating and is regularly turning into a variety of forms of something. Perhaps we live in a popcorn multiverse with an infinite number of big bangs going off all the time in ways we cannot not detect or fully imagine. Other universes may be sharing our space or off in other locales. We used to think there was only one galaxy: the Milky Way. Then we wondered if there were other inhabitable planets. We now know there are great numbers of both. Why should ours be the only universe? Or maybe our own yo-yo universe has an infinite set of cycles of trillions of years. However, for now we will prosaically restrict our attention to our own universe, or at least this most recent cycle of it.

Our current universe did not emerge immediately after the big bang full blown, only in miniature. Not only were there no humans then, there was no Earth. No Milky Way. No stars. There was just plasma, rather like the interior of our sun today. The infinitely hot and dense radiation immediately after the big bang was dramatic, but largely as uniform a situation as has existed in our universe's history. Incredible variation would emerge after the radiation period immediately after the big bang.

All but immediately after our own universe's big bang, when energy first congealed into normal or baryonic matter, six types of quarks appeared. They can appear again if protons and neutrons are smashed into each other at sufficient energy levels. Four of them led extraordinarily brief lives before returning to energy; they did not go on to form more complex forms of matter. However, two of them—the up and down quarks—did form relationships as they appeared. This will be a pattern. Some things go on to participate in emergent complexity. Many things do not.

At least those quarks that survived formed relationships. For a billion and one bits of matter that appeared, a billion bits of anti-matter with opposite spin did as well. Rather than playing well together, matter and anti-matter annihilate each other. This mayhem is a rather good thing from our point of view, since if all the matter that appeared survived, the universe would have been just too crowded to ever have developed into us. And plenty remained. Enough matter to eventually make a hundred billion galaxies each with an average of a hundred billion stars all have been formed by the leftovers of the great annihilation. Destruction can be very creative.

The lucky surviving quarks do not exist in isolation; they always exist in threesomes. Their relationship is structured by the strong force that is mediated by the exchange of the charmingly named gluons. Two up quarks and a down one form a positively charged proton; two downs and an up form a neutron. Why is the strong force exactly as strong as it is and not weaker or stronger? Is it different in other universes?—Who knows? It is just the way we do things in our universe. But if it differed at all, we would not be here and neither would anything else that we know of.

The quarks do not merge into one undifferentiated blob. Each proton and neutron is constituted by two different types of quarks. They relate to each other through the strong force, but they keep their distance as well. Relative to their own size, quarks have a rather pronounced need for personal space. Each of these three move in a constant dance around the others. They are always related, always moving, always distinct. Nature at rest is hard to find. Nature is spinning, moving, and restless.

The protons and neutrons that were formed quickly after the big bang are with us still after almost 14 billion years. In fact, they are us, and everything else that we can see or feel. The structured relationships among individual quarks have been remarkably sustained. As inventive and creative as nature is, it also keeps certain things around for a long time. If liberalism is about change and conservatism about keeping things the way they are, we can answer an interesting question. Something came from nothing at the big bang. That is change. Quarks can maintain their relationships for tens of billions of years. You can't get much more of a status quo than that. So is the universe liberal or conservative? Every inquiring person wants to know. And the answer is—yes.

About 300,000 years after the big bang, when the universe had expanded enough to cool sufficiently, the electromagnetic force mediated by the exchange of photons could structure a sustained relationship between positively charged protons and negatively charged electrons. Atoms appeared. Hydrogen, with one proton and one electron, appeared in the greatest numbers. If you add up their mass, about three quarters of all atoms in the universe are still hydrogen. If you count atoms by number, they constitute about 90% of all atoms. They also constitute 63% of the number of atoms in your body (10% by mass). As has been said, hydrogen is an odorless, colorless gas that, given enough time, becomes you. And me. And Congress; it's not the quarks' fault.

Helium, with two protons and two electrons each, formed about a quarter of all atoms' mass that then existed (9% by number). There was also a dash of deuterium, or heavy hydrogen (one proton, one neutron, and an electron), helium isotopes, and lithium (three protons and electrons). Vast primal clouds of hydrogen and helium atoms, millions of light years across, still majestically float in certain areas of space nearly 14 billion years later. Some have gone on to form greater complexity; many have not. Sometimes complexity emerges; more often it doesn't.

Once formed, and left on their own, these atoms tended to keep their distance. While the strong force bound quarks together and protons and neutrons together within atoms, these atoms left to themselves generally liked their own company. They might approach each other as they moved about, but usually swerved off, avoiding connections with each other. Helium had virtually no interest in other atoms. A hydrogen atom might hookup with another one, but that is as far as it went.

We sometimes hear about an "atomistic society." This usually refers to a rather asocial condition in which individuals have little to do with each other. The analogy might be a billiard table, with hard billiard balls usually sitting by themselves, but occasionally knocking into each other, sending each other off in various directions. Atoms may be the basic building blocks; in our experience, blocks usually just sit there by themselves. We are each made of about $6.7*10^{27}$ atoms. What are we, then, like at our most constitutive level? Are we like the individuals discussed by Hobbes in the *Leviathan* (1651)? Do we live lives largely isolated from others? By nature, are we as asocial as atoms? Should libertarians seek out new sympathizers among the universe's vast majority of unaffiliated atoms? If we seek to form relationships, do we need to find ways to overcome our natural proclivity for individualism? Are atoms the ultimate existentialists, destined to live lives of lonely desperation and then die alone, on a dark, rainy night? And since we are built from atoms, is that what we are really like, all niceties aside?

But what if the story is one of emergent relationship rather than individualism? Recall that even the simplest of atoms—those that have only one or two protons and are still the most abundant in the universe—are each a set of sustained, structured relationships. Quarks which just moments before had not existed, started to be related through the exchange of gluons mediating the strong force. Atoms, which had not existed before the big bang plus 300,000 years, added a relationship between protons and electrons. Atoms are sets of sustained, structured relationships.

At our most constitutive core, we are built more from relationships than from building blocks. Quarks and electrons are more fuzzy than blocky. And there is relatively a great deal of space between quarks within protons, and between protons and their electrons within atoms. The "hardness" of matter comes from forces defining the relationships between things that are far apart. What exists between things is as real as the things themselves.

Stars

But what about atoms naturally avoiding each other? Positively charged protons avoid each other. Helium has little interest in any combinations, and hydrogen by itself doesn't go beyond becoming H_2. Clouds of these atoms millions or light years across would not have led one 13.7 billion years ago to be very optimistic about the eventual emergence of anything much more complex. Relationships within atoms of one or two protons are fine, but beyond that, nothing much happens by these two types of atoms by themselves. Happily for us, these hydrogen and helium atoms were not left to their own devices. They existed within a larger framework that acted upon them.

When they did form, atoms were not perfectly distributed, if by "perfect" you mean "absolutely equally." They were a little more densely distributed here, a little less there. This asymmetry, unequal distribution, or imperfection was another very fortunate occurrence. Gravity has no force at the incredibly small distances between quarks. However, the space between atoms can be just enough to let it start operating. A clump of atoms here can exert gravitational attraction on a smaller clump there. If all atoms had been equally distributed, their gravitational attraction on each other would have canceled it all out, and they would never have been drawn to each other. However, with the asymmetry, the denser regions could start drawing in the slightly less densely packed atoms. Gravity kept pulling them together, increasing their density and heat. As they were pulled closer together, they began to spin faster like a figure skater drawing in her arms. Once sufficient density and heat developed, with atoms moving about more and more quickly, the protons within atoms overcame their preference to stay away from each other. Hydrogen nuclei began fusing. They not only ran into each other; hydrogen nuclei could stick to each other, forming helium, with its two protons and two neutrons, all held together by the strong force. Gravity was the great matchmaker for atoms that on their own would have stayed standing awkwardly along the wall at the middle school dance.

But the newly joined atoms were less than the sum of their parts. Each new helium atom weighed slightly less than the hydrogen atoms which had combined to form it. The missing matter had turned into energy. The fusion caused energy to burst out. Gravity kept trying to draw the atoms in. The equilibrium between these two forces resulted in the formation of stars. The black sky began twinkling. Not only can there be new things under the stars, the stars themselves were something new.

As the helium was formed, gravity drew it in more, until it heated up enough for it to start, within a couple hundred million years of the big bang, fusing into heavier elements, such as nitrogen. This released energy and permitted gravity to draw the newly formed elements further in, until they too began to fuse, forming carbon and neon. This was repeated as oxygen, magnesium, silicon, and sulfur were each fused. The largest stars with enough mass to permit gravity to keep drawing the newly fused elements further in developed an onion-like structure, with the lighter elements on the periphery; the heavier ones successively formed layers closer to the core. Each layer required higher temperatures to fuse even heavier elements. The strong force, electromagnetism, gravity, and fusion formed relationships between increasingly heavier atoms within the structure of a star.

Gravitational attraction between stars and perhaps dark matter formed galaxies or groupings of stars in distinct patterns. Galaxies formed relationships due to gravity in local groups and even larger patterns. The theoretical work of Fr. Georges Lemaître, confirmed by the evidence collected by Edwin Hubble, demonstrated that not only were there more galaxies than our own Milky Way, but that once they got to be further away from each other than those in the local group, they are racing away from each other. It may be that dark energy or anti-gravity is causing the galaxies to keep falling out, with space and the universe expanding at ever faster speeds the further from each other they are.

When the largest of the stars began to make iron with its twenty six protons, energy was consumed rather than released. The equilibrium between gravity and fusion was broken. Almost immediately, the star exploded in a supernova. The sudden increase in temperatures during the explosion permitted the almost instantaneous formation of all of the elements with more than twenty-six protons per atom, all sent streaming into space at incredible speeds, often mixing with pre-existing clouds of hydrogen and helium that had been floating since the big bang.

Minerals and Molecules

Some atoms organize themselves in structured patterns. A couple examples of this in early space came from carbon atoms. Fitted together in one way at certain temperatures, they formed diamonds. Fit together in a different way at another temperature determined by distance from heat sources of stars, they form graphite like in our pencils. These are among the first minerals that existed space early in universal history.

There can also be bonds between different types of atoms. Atoms form in such a way that electrons orbit protons in shells. The innermost shell is full with two electrons, the second with eight, the third with eighteen, the fourth with thirty-two, the fifth with fifty. Hydrogen, with its one electron, has a vacancy sign out in its only electron shell. That shell seems to want one more electron to form a full house. Oxygen, with its eight electrons, has two in its first shell and six in its second. This leaves two vacancies in its second shell. This is a match made in the heavens. If two hydrogen atoms hook up with an oxygen atom, each sharing their electrons, each hydrogen atom can have two electrons in its only shell and oxygen can have eight in its second shell. Everybody is happy because a new relationship between atoms is formed: H_2O—water. This molecule has a new property. At the right temperature, it has the property of wetness, which did not exist before. Water, which is abundant throughout space, is not the only molecule that forms. Dozens of molecules with two, three, four, five, or more atoms evolve naturally. Many atoms due to the way electron shells work lead to the formation of these new relationships called molecules.

Not all atoms are anxious to form molecules. Helium has two electrons in its only shell and has a *No Vacancy* sign well lit. It is called a noble gas. Having all they need, nobility does not require additional relationships with the lesser types that are needy. Relationship added to relationship is not much part of helium's story. While hydrogen becomes us, helium often just goes floating off into space. Not everything is social. Not everything forms polity, or sustained, ordered relationships. We saw that same aloofness with four of the six quarks. A subatomic particle formed in nuclear fusion, neutrinos, are much the same. Like photons, they go shooting from stars off into space, but almost never interact with anything. They can sail through twenty miles of lead and never hit anything. It has taken extraordinary measures to detect them at all. History and polity are not built on the backs of two-thirds of quarks, neutrinos, helium, or other asocial phenomena. They are indeed the rugged individualists of the universe. The story of emergent complexity is not uniform.

Earth and the Emergence of Life

After a nearby supernova shot its star dust out into neighboring space, disturbing pre-existing clouds of hydrogen and helium, gravity again began pulling together the mixture of elements and molecules. A second generation star with mostly hydrogen and helium but also with traces of heavier elements in it—including oxygen, carbon, neon and iron—eventually began shining as our sun 4.6 billion years ago. It is not big enough to permit gravity to create densities high enough to fuse elements heavier than helium. This is good for us, since huge stars live fast and die young. Our sun goes along at a nice leisurely pace of fusing 600 million tons of hydrogen each second, turning it into 596 million tons of helium and more energy than mankind has ever produced in our species' entire history. It is because of all their mass that stars like our sun produce so much heat and light.

The sun's rate of consuming its stock of hydrogen will permit it to continue shining for a total of about 10 billion years, meaning it is at mid-life now. Its 5 billion year history has provided energy and the time for Earth to develop. We've got billions more years before the sun turns into a red giant, evaporates the oceans and engulfs the earth. There is plenty of time before anyone needs to get tickets for a trip to another solar system.

While gravity drew together 99.86% of the total mass of the solar system to make the sun, the leftover debris went to good use. On the outskirts of the spinning disk that eventually ignited as the sun, these leftovers from part of the supernova started accreting through the power of gravity. Chunks of iron, nickel, silicon, and bits or gold, silver, uranium, and other elements and molecules bumped into each other and stuck together. All this knocking together that created kinetic energy, not to mention the radioactive decay of uranium and other such elements, made for a molten, hot planet that formed its own structure from thousands of molecules and the minerals they produced. Heavier iron and nickel sunk into a dense core that is still as hot as the surface of the sun. Silicon and other lighter elements rose to the top. Eventually, a thin layer made of the frothy basalt and granite could cool enough to permit the ocean floor and land to form. Lighter, cooler outer layers spinning around denser iron and nickel produced a magnetic shield around the planet that protected it from solar winds that would otherwise blow away Earth's atmosphere.

The process of chemical evolution that had begun in space continued on Earth. The most common elements on the surface of the Earth continued to combine in many ways. Hydrogen, carbon, nitrogen, oxygen, sodium, magnesium, phosphorus, sulfur, chlorine, potassium, calcium, iron, and other elements on earth interacted to form over 4,700 minerals. Around black smokers at the bottom of the oceans where tectonic plates separated and mineral-rich, heated waters bellowed up, or on sun-soaked pools of water on rocky beaches, the process of chemical evolution continued. Lipids that created films formed, eventually forming membranes. Carbon, with its four electrons in its second orbit and a total of six overall, was able to combine with many other elements, and was central to the Krebs cycle which spins off amino acids. These molecules continued to combine until they integrated membranes, metabolism or access to energy, and RNA and DNA that permitted reproduction with variation in response to environmental changes. The Last Common Universal Ancestor—*LUCA*—was combined in the most complex relationship in universal history to date, that we know of. The first prokaryote cells were earthlings, formed of the commonly available chemicals and elements on Earth's surface. They were also children of the universe, with elements forged in stars that had died long before.

Biological Evolution

It has been said that the dream of every bacterium, the simplest of cells, is to become two bacteria. Reproduction has to be important for any species that plans on surviving, since the death of any given individual is part of the way life works. Sustained relationship is not eternal relationship. The nice thing about being a bacterium is that your dreams can come true about every twenty minutes. Reproduction with variation in response to environmental changes is a skill perfected by prokaryote cells. You just can't argue with success. They live in virtually any setting, however extreme the condition on earth can be. From deep underground to thermal waters, prokaryotes are there. There are more bacterial cells in and on your body than there are cells that constitute your body. They help you digest food. And when you die, they will digest you. These types of cells have survived for almost 4 billion years. They will be on earth long after humans have vanished. Many prokaryote cells follow a plan that isn't broken and doesn't need fixing, although they do keep adjusting to new conditions such as antibiotics. They evolve quickly, but as a group, they have not become fundamentally more complex.

However, after a couple billion years of happily reproducing at their same level of complexity, some did become more complex. About 2 billion years ago, eukaryote cells developed with a membrane covered kernel in which more complex DNA was kept. It also began hosting a mitochondrial cell, which provided an ability to burn carbohydrates and permits us to enjoy eating donuts.

A more complex set of relationships within the cell led to more complex relationships among cells. Films of bacteria on the surface of the ocean or accretions of them in rock like formations of stromatolites in tidal pools were steps towards multicellular life forms. Another step in multicellular cooperation came with creatures like the sponges. These are formed by the same type of cells that could still specialize in serving different functions. Some cells drew in nutrient-rich water; others expelled nutrient drained water. Same type of cells; different tasks. Push these cells through a sieve so that they are separated as they fall to the bottom of a tank, and they scoot back together to form another new sponge. These are cooperative cells, not hardy individualists.

Relationships among increasingly complex body structures formed by different types of cells are seen in such examples as cnidarians, or jellyfish, first seen about 800 million years ago. They have little harpoons that can inject prey with poison, have such structures as a mouth/anus, and have two layers of tissue. Their nervous system is pretty uniformly spread out throughout the animal. Jellyfish are still around and doing fine. The Scarecrow in the *Wizard of Oz* seemed to get along pretty well without a brain, and so have the cnidarians. They have existed 4,000 times longer than *Homo sapiens* have. They see no reason to develop more complexity.

Still, there were additional mutations that worked out in the environment of the time. Flatworms introduced a body plan about 590 million years ago with a right and a left side, an up and down, and a front and a back. Sense organs were put up front, along with a ganglia of nerve cells to interpret the incoming data. Chordates like the currently existing hagfish put a cord along its back to protect the flow of information from the ganglia to the rest of the body, as well as putting the mouth up front and an anus in the rear. About 525 million years ago, vertebrates started breaking that cord into bony segments, offering better protection and definition. The first animals to venture out from the seas onto land, such as *tiktaalik*, had wrists to help scoot on land and a neck to help look around. About 360 million years ago, the first amniotes could recreate the watery world in which reproduction had originally taken place, and start producing eggs with a protective shell and watery interior. About 360 million years ago, mammals first appeared, which had, among other things, a more complex auditory system with more parts that helped them hear better. The story of evolution is in part a story of increasing complexity of body structures, with more complex relationships among greater numbers of parts.

It is worth recalling a few things: First, part of the reason for this development was in response to the bitter competition between and among species. An arms race of those seeking to eat others and those seeking not to be eaten was good to select which individuals would survive to reproduce the next generation. Increasingly complex relationship was spurred in part by harsh competition. Secondly, there was no steady rise from simplicity to complexity. Five major extinction periods between 450 million years ago [mya] and 65 mya caused huge interruptions. This is only part of the reason why over 99% of the species that have ever existed are now extinct. We may be going through a sixth (self-induced) extinction period that we hope does not conclude with our own species' disappearance. It would be a shame to be a mere 200,000 year-long flash in a pan.

Relations among Animals and Plants

Relationships among quarks, protons and electrons, atoms, molecules, cells, and body parts were followed by increasingly complex relations among and between species. Edward O. Wilson's *The Social Conquest of the Earth* (2012) offers a fascinating discussion of this phenomenon.

From quorum sensing of bacteria to schools of fish, bee hives, ant colonies, flocks of birds, herds of bison, troops of chimpanzees, and many other examples, animals often live in groups and groups often form ecosystems.

Not all animals live in groups. Many seem to exist in splendid isolation for most of their lives, coming together just long enough for reproduction without any care for offspring after birth. Mother guppies and sharks would just as soon eat their babies. Sea turtles lay their eggs on the beach, return to the sea, and may hope for the best for their offspring, but likely don't think about them. Crocodiles help their offspring out of their eggshell and out of the nest; after that, the kids are on their own. Childcare is of course more of an issue for various lengths of time for many species. From weeks of care to a couple years is common. Mothers, fathers, and others are involved in different ways, depending on the species.

By the time we get to hominins, our ancestors' survival strategy and increasing sociability went hand in hand. *Australopithicus* and its ancestors were likely more often the hunted than the hunters. They may have scavenged, eating bone marrow of leftover carcasses, but gathering fruits, nuts, tubers, and leaves likely provided a mainstay of their diet. Other than that, they tried to stay out of the way of predators. They had few natural weapons. Their teeth were no match for those of lions. Their speed was no match for cheetahs. They had neither shells for defense nor wings for flight. No wonder that there do not seem to have been huge numbers of hominids, that most species went extinct, and that our own ancestors came close to extinction. They just did not have that much going for them.

Bipedalism, for whatever reason it was adopted, did permit more use of the arms, hands, and opposable thumbs. A parent could hold a child and pick fruit all at once. But it also altered the skeleton, restricting the birth canal, making childbirth that much more dangerous. This became a greater problem once the hominids' greatest weapon did finally start to develop. Brain size from *Australopithicus* to *Homo sapiens* tripled, with Neanderthals winning the brain-size competition. (Brain size for *Australopithicus* averaged between 375 and 550 cm^3, *Homo habilis* from 500 to 800, *Homo erectus* 750 to 1225, *Homo Sapiens* 1200 to 1750, and Neanderthals 900 to 1880 [Sawyer et al. 2007, 18, 58, 65, 79, 87, 96, 107, 117, 124, 133, 141, 151, 158, 168, 176, 185, 194, 201, 210, 222].) Hominids couldn't outfight competing species, but they could start to outthink them. Brains rather than brawn would eventually win the day.

Even with only partial brain development and soft skulls at birth, delivering children had become highly risky. To permit time for the brain to develop to maturity, grow a bony skull, and learn all that they required to survive, childhood for hominids took years. Breastfeeding and childcare-giving mothers developed close relations with offspring over long childhoods.

Child mortality was still likely high. For a handful of children to reach sexual maturity, birth would need to be given to a number more. Especially with life-spans in the 30s or so for adults who got through childhood, this meant that most or all of a female's adult life was involved with pregnancy and childcare. Working mothers were the norm. They likely provided the bulk of the calories through gathering and carried out many other important tasks. Still, they would have needed support as they did the primarily important work of getting children to adulthood so the species could survive. Long-term relations between mothers and children and between child care-taking females and males were necessary for the fat-headed hominids to survive.

It is one thing to get together briefly to copulate. That is all sharks need to do since child care is not a problem. It is a wholly other set of problems to stay together for many years to raise children, a problem that hominids did have to figure out if they were to survive. Resolving the issues of food, shelter, and other necessities for a kinship group over years takes problem-solving and relationships to a whole different level. The increased demands of a long childhood and the long-term adult relations it required selected for an increased ability to figure out how to live together for many years at a time. The gender relations made necessary by being a big brained bipedal species is a root of hominid polity. Sexual politics has changed markedly recently with longer life spans and lower mortality rates. Mothers no longer spend their entire adult lives dealing with pregnancy and childcare, and have the time and energy to do much else.

Many species have long developed their own ways of developing and maintaining relationships. Baboons groom each other, checking for parasites in the fur. Frans de Waal (2006) discusses how bonobos use sex for much the same purposes. Social primates, who were not genetically identical like ants within a colony are, developed a "theory of mind"; they could understand each other's reactions. They could even sometimes "feel for each other," or empathize. The law of the jungle, as de Waal argues, includes the social practices and understandings that would later be self-consciously developed into ethics (2006, 1–3, 182–87, 197–8, 225, 247–8; 2009, 6–7, 20–21, 25–29, 122–24, 138–39).

Picking lice out of children's hair and having sexual relations has forever been part of hominid mothers' lives as well. Hominids' survival strategy led to developed abilities to relate to each other. For their relations to develop, they would need to exchange a lot more than just gluons and photons. If you thought physics was hard to grasp, just try politics.

Memory, Imagination, Symbolic Thinking, and Exchange

Virtually all species remember, although in very different ways. The long childhoods in which each person remembers their period of dependency creates long-term memories of caretakers. Hominid adults still remember their own childhoods and their caretakers. They remember how these important experiences were carried out by those who are now old or dead. What was so important is now gone, but remains important in memory. Memories of what is no longer may be pondered while going about present tasks.

Child-bearing for hominids also entails the expectation of repeating a long-term set of relationships. I am going to have to do for my children what was done for me. This baby will require years of nurture to get it to sexual maturity. What is a baby now will in a number of years become an adult if I do what I need to do to help it survive. I can imagine a long-term future which does not yet exist, but which I can help create. Memory, imagination, planning, and execution go hand in hand.

Being able to remember what no longer is—and imagine what is not yet—is facilitated by symbolic thinking and language. Vervet monkeys will make one call for threats from above such as an eagle, another for threats in trees such as snakes, or those on the ground such as big cats. When one monkey makes such a call, others in the troop look in the right direction. One screech signifying eagle causes other monkeys to look up. A sound and an expressed/perceived meaning are linked correctly, helping the group's survival. However, the monkey does not make the sound in the absence of the threat. They do not discuss how to better prepare for a future threat. Vervet monkeys do not sit around at night discussing that day's eagle attack. They do not draw pictures of eagles. They do not intellectually manipulate or exchange symbols.

The development of syntax or grammar and vocabulary went along with that of symbolic thought. Being able to consider words and meaning in the absence of immediately present referents, adjust them, move them around and think of alternative arrangements, was facilitated by language. Being able to communicate these ideas in novel yet understandable ways meant that new meanings could be created.

Remembering and imagining in the absence of the referent is a source of symbolic thinking, planning, and eventually realizing possibilities. The road from the communication of monkeys to the symbolic thinking of hominids is long, complex, and still not exactly understood. But that it took place seems clear. By over two and a half million years ago at the Gona River in Ethiopia, *Australopithecus* or *Homo habilis* was making stone tools. Other species use tools as well. Crows, wolves, chimps, and others will use stones and sticks to achieve various purposes. However, the Gona River chipped tools were fashioned by toolmakers. They had to first select which type of rock they wanted to alter. Some types of rock are too soft to make good tools. Then they had to be able to imagine the tool that was in the right kind of rock, to imagine how it could be made into a cutting, scraping, or digging tool. Then they had to carry out a series of steps to create the tool. This was probably done with others looking on and learning how to do this as well. And remember, all of this was going on over two million years before *Homo sapiens* appeared.

Tool-making was added to older tool-using skills when symbolic thinking and imagination was possible due to eye-hand and brain development, relative to earlier species. Those who had emerged from nature now began to adjust what they found in nature. Nature in these complex pockets called hominids could begin to select what helped them survive and live better. Evolution could begin to be not only in response to environment, but determinative of it. Nature became partially self-selecting in hominids.

Nature had long exhibited how creative it is. There was nothing and then there was something. There were not protons and then there were. Same with atoms, molecules, stars, terrestrial planets, and life. The transition from one to the next is a time of change and natural creativity, but there were long periods of stasis in between each one. Relative to these periods, the time it took for hominids to develop their tool-making was rather quick, even if it seems to be agonizingly slow to us. By the Oldowan period from about 2.6 to 1.7 million years ago, *Australopithicus* and/or *Homo habilis* had developed more sophisticated tools. By the Acheulean period about 1,650,000 to 100,000 years ago, tools had become bifacial, larger, and more varied. The oval or pear shaped tools are not only functional; they also have shapes that are pleasing to us and perhaps to their makers. Natural emergence had become hominids' creativity. The road from physics to art was being paved.

Adjusting nature was done in various ways. Eating meat and tough tubers was hard on the digestive tract of early hominids. Cooking them made them easier to digest and taste better. Exactly when this began is not certain, although it seems to have started between 1,500,000 and 790,000 years ago with the fire-altered stones at Gesherbenot-Ya'aqov in Israel. The transition from scavenging to hunting had been made at least by half a million years ago, as indicated by spear points and skeletal wounds in prey found at Boxgrove, England and Kathu Pan 1 in South Africa.

Burials indicate a new level of relationship. Other species such as elephants will clearly mourn dead members of the group. But the careful burial of the dead is a human activity. Again, exactly when this began is not clear, but there are burials from 80,000 to 120,000 years ago in Qafzeh, Israel. Here, we have living members of the group remembering the people who had died and imagining they have an obligation to them even after they die. Burial is a relationship with the dead, requiring memory of who is no longer. What is real in the present is only part of what matters. Memories of the past—kept in the electrical/chemical relationships among neurons—can be more important than the hard stuff that one can feel now in the present.

Hunters had long understood the difference between life and death. Causing an animal to bleed from wounds transformed the beast from one running through the woods to one lying on the ground. Did the hunters begin to think symbolically about the "life" being in the blood that sank into the ground? Does the life of the body go into the earth looking for a new form to inhabit? Is the spirit of the dead animal believed to be angry at the hunter, planning to return to the surface world to make trouble if proper steps of propitiation are not taken by the hunter?

Once grave goods become included in the burials, we seem to also have imagination of the future added to memory of the past. Burial goods suggest that people thought they could indeed take it with them. Everything had a spirit: people, mountains, rivers, pots, weapons, etc. The life or spirit of the dead person will need the spirits of various tools or weapons in the next life. Members of the group were socially close to those now dead. They remembered them and valued these memories. They wanted to imagine that their beloved would live on, and that proper actions by the living could help the dead live well. Ancestor worship may be one origin of religion. This seems to indicate the powerful social attachments our ancestors had with each other.

The discoveries at Blombos cave in South Africa from about 75,000 years ago include an etched, rectangular rock. A net or diamond like design is scratched, with diagonal and parallel sets of lines. This is not just aimless doodling. This is done by a person interested in perceiving and creating patterns. What other patterns were being perceived and analyzed? Seasons? Plant growth? Movements of animals? Behaviors of fellow members of the group? Did the patterned lines have symbolic meaning of some sort in a way that etched crosses, six pointed stars, or crescents often have for us?

Shells with drilled holes were also found at Blombos. The cave is near the coast, and a diet of sea food sustained them. Did they wear the shells as a way to offer the spirits of the dead animals a place to live after their bodies had been ingested? Did they wear necklaces of shells out of a sense of beauty made possible by using or improving on what nature offers? What do these artifacts indicate about their symbolic thinking?

Migration from Africa

About the time that people at Blombos were etching patterns in a rock and drilling holes in shells, others in northern Africa were beginning to leave Africa, where it seems now that they had all evolved. This had happened again over a million years earlier with homo erectus, who made their way all the way from Africa to East Asia before eventually dying out much later. About 80,000 years ago, homo sapiens were unknowingly retracing many of the routes from Africa, across modern day Sinai, Israel, along the coast of India, East Asia, up to Central Asia, and by about 50,000 years ago by boat to Australia. It would take tens of thousands of more years to figure out how to survive Siberia before by about 20,000 years ago people made their way across Beringia (the land bridge before about 10,000 years ago between Russia and Alaska) to what truly was then a new world for hominins in the Americas. It may well be that our kind existed in extraordinarily small numbers 80,000 years ago and that there was a common ancestor for all currently living people who lived at that point. It is almost certain that we were all Africans originally, and our subsequent differences in appearance evolved since the great migration from Africa.

It was only after Asia had been populated that homo sapiens made their way to Europe. They brought with them the symbolic thought that they had been developing in other areas. By perhaps 48,000 years ago, at the El Castillo Cave in Spain, an artist painted animals and designs from dots and lines on the walls. This was the case later as well at Chauvet, Lascaux, and elsewhere. The animals that were painted were not modeling for them. The artists worked from memory. What purposes did they have in painting these animals and designs underground? What were the artists thinking about the animals and designs they painted? It is hard not to speculate. Was the cave where the spirits of dead animals went to live after their blood drained from their bodies? Were these spirits looking for new bodies to inhabit? What was the meaning of the paintings for those who drew or first viewed them? The artists also spit-painted the outline of their hands multiple times. Were they leaving their signature, wanting those who would view the painting in the future to know who painted them? Were they touching the rock behind which the spirits of the animals they painted lived?

The importance of reproduction and fertility is made explicit by the so-called Venus figures found at Hohle Fels in Germany from the Upper Paleolithic period, the Woman of Willendorf from about 24,000 years ago, the Woman of Laussel from about 20,000 years ago, and many others. These palm-size statuettes of women with exaggerated breasts and hips may have offered comfort to mothers going through pregnancy or delivery, or had any number of other possible meanings. Whoever made the statues did so while thinking about fertility and sexuality rather than engaging in sex. These statues demonstrate symbolic thinking about sex in the immediate absence of sexual behavior.

The big history of music is also noteworthy. The hardware necessary to transforming the waves through a medium such as air into perceived sounds in the brain began with early land dwellers feeling vibrations in their bones. Sight is great, but you can't see around the bend or over the hill. Sound provides crucially important information. The patterns and tones of sound provide important information about the environment. Many species produce sounds as well as perceive them. Some birds will sing to announce territorial claims or attract mates. Whales and others too will sing to communicate over long distances. Sounds can convey information to others.

With the malleus, incus, and stapes as part of their auditory system, mammals became able to hear in ways that reptiles cannot. Listening to the sound waves caused by ocean waves, lion roars, chirping crickets, and howling winds all had important meanings for hominids. Hearing and responding to a dependent babies cry, parting the lips and calling "Ma" with various inflections of tone elicited powerful responses among caretakers. Different sounds would have elicited other profound emotional responses, such as fear or sexual desire. Rhythmic music and drumming would have enhanced group identity during kinship groups' dances. Eventually, fife and drums communicated information and bolstered courage during battle. Campaign theme songs would identify candidates. National anthems would stir patriotism. Perceiving and making music has a long history of the relationships between animals and their environments, and animals such as humans with each other.

Symbolic thinking and imagination made combination beyond natural referents possible. A wonderful example of this is the *Löwenmensch*, or Lion Man, from Germany from about 30,000 years ago. A bipedal man's body with a lion's head was not something the artist had ever seen. This was work not from memory alone but from imagination and combination. This indicates the ability to manipulate symbols separate from natural perception. It also indicates a crucially important political ability of combining what had not yet been combined in nature.

Nature had combined much in the past through increasingly complex relationships. Quarks, atoms, molecules, minerals, cells, body parts, animal groups, and ecosystems all kept putting things together in larger and novel combinations. Now, humans could do this at a faster pace and self-consciously.

Placing value on symbols for their own sake was exhibited by early artists as well. For example, there is a beautiful ivory horse sculpture from Vogelherd, Germany from about 32,000 years ago. The artist did not try to include all the musculature of a real horse. Instead, it is an idealized shape with a series of flowing curves. This is not so much a representation of a physical horse as an ideal one expressing a sense of beauty. The artist took delight in abstraction. Plato was a bit of a Johnny-come-lately with his theory of the forms. Relationships through the exchange of words, music, and symbols developed human relationships. Exchange of goods did, too. This too has a long history, going back to sharing food to enhance group relations.

Specialized tool production *Homo habilis* sites relatively far from sources of rock that were used indicate trade as much as two million years ago. Trading routes become increasingly extensive and established until by 14,000 years ago the obsidian trade in the Near East and then the famous Silk Road established what some see as a central core political system.

Political and Social Development

Kinship

The growth of symbolic thinking and exchange of goods, words, glances, gestures, musical sounds, and artistic images facilitated political development. We have discussed the importance of kinship groups. Long-term bonding of childcare givers required sophisticated relationships demanding lots of exchanges. Kinship groups within a scavenger/gatherer and then hunter/gatherer economy likely became complex, but were still limited in size to perhaps fifty or a hundred persons. Larger trading routes would have permitted development of complexity of relationship. Family groups needed to exchange offspring for mating in the next generation. This led over generations to complex sets of inter-kinship relations. Terms such as “second cousin once removed” start to indicate such complexity.

In kinship relationships, lineage is important. Loyalties are to caretakers and common ancestors. Family and kinship remains important in our own day. The powerful resonances are indicated by larger groups attempting to appropriate kinship relations. Nationalists sometimes have referred to their country as a Motherland. In the United States, George Washington is referred to as the “Father of the Country.” Members of the Roman Catholic Church call their priests “Father.” Larger, non-lineage groups often seek to call upon the powerful forces of kinship. One of the values of big history is its scientific story of the real lineage of all persons, going back to a small group in Africa about 200,000 years ago; of all life to *LUCA*, and the universe to a single point. It turns out that we really do all have a common background. Big history is the scientific story for a period of human politics.

Agriculture and Villages

One of the major thresholds of big history is the agricultural revolution. The transition from hunting and gathering to growing crops and raising certain animals is of crucial importance. It also entails a stage of political development. Hunting/gathering went along with kinship polities. With agriculture came settled villages of increasing size, beginning to include different kinship lines. This presented the village with an enormous political problem: how to establish a sustained, structured set of relationships beyond kinship.

One way to do this was to create dynasties; village lineages that all could be persuaded or forced to adopt. Lineage now became a symbolic political category rather than a biological one. In many regions of the world, mounds and other monumental burial sites enshrined the lineage of the village. Those within one lineage might still have the right to rule, but all needed to exchange the symbols that helped nurture loyalty to it.

The political leaders of these settlements or villages during the early agricultural era were sometimes those who had access and control over the best growing areas. We start to see increased social stratification and inequalities in wealth as the agricultural era proceeded. Some residences and some graves are noticeably grander than others. Hierarchy in the hunter/gatherer era was more likely based on strength, size, or cunning. In each period, leadership could also be exercised by those we call shamans, or those who could impress their fellows with their special insights and relationships. When some went through fasting, whether by choice or necessity, carried out rhythmic dancing while listening to repetitive rhythmic music, added various hallucinogens, and perhaps inflicted self-flagellation, they likely could report any number of special insights and experiences. Shapes would have shifted, experienced as traveling in other realms. These were similar to dream-like states. Dreams while sleeping and trances while awake offered symbolic connections with what was beyond normal referents. Imagined relationships with abstract designs, ancestors, and the supernormal by some could have impressed others and established a claim to leadership.

Village identity could be developed and expressed through styles of clothing, certain verbal expressions, or other identifiers. Stories about the village could be told at gatherings. It took enormous effort and creativity to incorporate loyalty to the family within loyalty to the village.

Cities and Empires

Monumental, ceremonial architecture reinforced the claim by some of symbolic leadership that legitimized claims to political leadership. Standing in awe not directly of the universe, but of some people’s special connections with it, was impressive. From Watson Brake in Ouachita Parish in Louisiana from about 5,400 years ago to Imhotep’s Saqarra in Egypt about 4,700 years ago, grand burial sites began to announce the emergence of full-time leading families. Large, stylized burial mounds called attention if not of the gods, at least of the humbled onlookers who stood before them during ceremonies. Equivalents in modern America are the tall, stiff obelisk in honor to the Father of the Country, or the Jefferson or Lincoln Memorials in which political pilgrims can stand reverently in front of larger-than-life leaders who have mythical meaning and personify the presidential succession that leads to the current national leader.

Large, monumental architecture also announces the emergence of new political units of cities with larger populations and relations of cities within regional associations and nations or empires. Eridu, Uruk, Ur, Çatalhöyük, Jericho, Damascus, Mohenjo-daro, Tenochtitlán, Teotihuacan, Xi’an and other great cities represent a transition to larger, more complex political units. Sometimes these became the hubs of empires; sometimes they were combined with other cities within empires such as the Akkadian Empire of Sargon the Great from 2,400 BCE, the fifteenth century BCE New Kingdom of Ancient Egypt ruled by Thutmose III, the Assyrian empire of 2000–612 BCE, the Median Empire in Persia by the sixth century BCE, the

Achaemenid Empire from 550–330 BCE, the Mauryan Empire from 321 to 185 BCE, the Roman, Han, Byzantine, Qing, Mongol, Arabian, Ottoman, Ashanti, and Mughal empires.

The modern European empires were transformative through their incorporation of the Industrial Revolution. The British, French, Dutch, German, and Japanese empires were built from steel, oil-powered ships, railroads, and gasoline-powered vehicles. The Russian and American empires combined these in the information age with nuclear power and nuclear weapons.

The struggles for power within empires and between some of them are the stuff of traditional history. The endless lists of battles and army flanks can make for a depressing account of the human past. Homer's account of the Trojan War is heroic enough, but it is also just another deadly battle scene. And things don't seem to have improved much. We started the twentieth century with a war to end all wars, followed by a horrific Second World War twenty years later. Since the end of WWII, there have been about 250 wars with over 50 million people killed, tens of millions more wounded, and countless made homeless.

Where are we going?

What can we conclude from our 13.82 billion year journey so far in this universe? The access to high quality energy in certain pockets has permitted increased complexity in relationships between quarks, atoms, molecules, cells, animals, and humans within families, cities, nations, empires, and the world. Each of the earlier relationships continues to be part of our current ones, although often in transformed ways. You and I are the beneficiaries of the relationships that have been developed. We are made from the relationships among quarks, atoms, molecules, cells, and many intricately related body parts. We live within kinship groups, nations, and empires. Many of us are connected with others around the world through the almost instantaneous exchange of digital information. We have evidence for a common origin of all of us and indeed everything it the universe. All of us on earth have a common origin and ultimately a common destiny.

Big history is ultimately not only about the past. It helps us understand what brought us to the present and how we may participate in the future through long-developed processes. Will we continue to have access to high quality energy and remain as the pockets which continue to develop the most complex relationships of which we are aware in the universe? Can we use this energy without polluting our world and making it uninhabitable? Even if the energy crisis is resolved in a sustainable way, do we have the imagination to combine national, ethnic, and other types of groups within new and meaningful relationships? Can we be as creative as nature was earlier when it first combined protons and electrons, atoms in molecules, molecules in cells, cells in plants and animals, and animals in various groupings? Can we be as imaginative as the artist who carved the *Löwenmensch*, imagining the combination of lions and people? Or the shaman who imagined how to combine kinship groups in the village? Can the study of big history be formative enough to teach us how to combine families, ethnic groups, cities, nations, empires, humans, and our environment in ways that protect all of them? Can this be done even while there are many in less complex relationships who show little or no interest in participating in big politics, who are satisfied with staying at their level of complexity? Can enough people make the transition to the next level of complexity? Can we fashion a more complex, sustainable, structured set of relationships? Can we experience politics as sustained, creative, structured relationship rather than a struggle for dominance? Can we understand ethics as developed from the empathy and sense of fair play that makes sustained relationships possible? Can we experience religion as the sense of awe of the forces that have bound us together and the creativity that leads to new and more complex, structured, and sustained relationships? Or will entropy overtake us before it needs to?

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