The Big Burp
and
The Multi-Planetary Mandate

By Howard Bloom

Founder of The Space Development Steering Committee.
Founder of The International Paleopsychology Project.
Author of *The Lucifer Principle: A Scientific Expedition Into the Forces of History* ("mesmerizing"—The *Washington Post*), *Global Brain: The Evolution of Mass Mind From The Big Bang to the 21st Century* ("reassuring and sobering"—*The New Yorker*), and *How I Accidentally Started The Sixties* ("a monumental, epic, glorious literary achievement." Timothy Leary).

8,352 words•

Evolution is shouting a message at us. Yes, evolution herself. That imperative? Get your ass and the asses, burros, donkeys and cells of your fellow species—from bacteria to plants, fish, reptiles, and mammals—off this dangerous scrap of a planet I've given you and find new niches for life. Take The Grand Experiment Of Cells And DNA, the 3.85 billion-year Project Of Biomass, to other planets, moons, orbiting habitats, and galaxies. Give life an opportunity to thrive, to reinvent itself, to turn every old disaster, every pinwheeling galaxy, into new opportunity. Do this as the only species Nature has generated that's capable of deliberate travel beyond the atmosphere of Earth. Do it as the only species able to take on the mission of making life multi-planetary. Accept that mission or you may well eliminate yourself and all the species that depend on you—from the bacteria making folic acid and vitamin K[1] in your gut to wheat, corn, cucumbers, chickens, cows, the yeast you cultivate to make beer, and even the bacteria you use to make cheese. What's worse, if you fail to take life beyond the skies, the whole experiment of life—including rainforests, whales, and endangered species—may die in some perfectly normal cosmic catastrophe.

Where does this imperative to pierce the sky and to fly beyond the well of Earth's gravity come from? What does it have to do with the role of culture in the cosmos? And, most important, how does the relationship between culture and the cosmos tell us that space is a key to our future, a key to our evolutionary obligations, and a key to our ecological destiny?

• Special thanks to Judy Rubin for proofreading this chapter and for giving daily encouragement.

Let's start with a basic question whose answer may come as a surprise. What is culture and when did it begin? Culture is the multi-generational hard-drive of memory, change, and innovation. Culture transforms a record of the past into a prediction of the future; it transforms memory into tradition—into rules of how to proceed. And culture is profoundly social. It exists not just in one mind, but binds together mobs of minds in a common enterprise.

When did culture first appear in this 13.7 billion-year-old universe? The answers are surprising. Most evolutionary experts say that human culture kicked off 45,000 to 35,000 years ago. Paleontologists studying pre-historic Europe call this period The Cultural Explosion.[2] 45,000 to 35,000 years ago,[3] men and women began to perforate, grind, polish, and drill bone, ivory, antler, shell and stone into harpoons, fish hooks, buttons, ornaments, sewing needles, and awls.[4] Frosting the cake, humans invented music,[5] calendars marked on pieces of antler,[6] and paintings on the walls of caves.[7] Then there's the **un**-standard answer about culture's beginnings, a rebel timeline of human culture that a relatively new paleoanthropological school is fighting for. This new scientific movement has made its digs in Africa, not Europe,[8] and has come up with radically different dates. Culture, says this upstart new school, started approximately 280,000 years ago[9] when humans invented the makeup industry,[10] then followed that up with the invention of jewelry, beads, and trade.[11]

But both of these paleoanthropological schools are wrong about the first birth of culture. Dramatically wrong. In 1997, we—myself and a cohort of colleagues—started a new discipline. Its name is paleopsychology. Paleopsychology's mandate is to "trace the evolution of sociality, mentation, cognition, and emotion from the first 10^{-32} second of the Big Bang to today."[12] Paleopsychology is cross-disciplinary. It embraces every science that its participants can bring to the table. Activists in the field have included physicists, mathematicians, microbiologists, animal behaviorists, evolutionary biologists, evolutionary psychologists, entomologists, mycologists, anthropologists, cognitive scientists, and neurobiologists. And paleopsychology gives a far different answer to the question of culture's starting date.

Culture didn't begin 45,000 or 280,000 years ago. Culture began roughly 3.85 billion years ago.[13] Yes, I said billion! It began when the cosmos was less than ten billion years old. It began when this planet was still so new that planetesimals—hunks of rock the size of small moons—were raining down on this globe's face, deforming this planet as savagely as the hard right of a boxer deforms the face of an opponent when it hits that contestant squarely and with full force on the side of his head.[14]

Culture is a social thing. And cosmic evolution set the stage for culture with a long string of social events. Much as we hate to admit it, the Big Bang was profoundly social. In its first flick, 13.7 billion years ago,[15] it set the first mob in motion. It precipitated roughly 10^{88} quarks.[16] Those quarks rushed into another social process—ganging up in groups of three, trios we call protons and neutrons. The social process of trio-making involved rules of etiquette, the laws of attraction and repulsion that dictate what sort of quarks you, if you were a quark, should hook up with and what sort of quarks you should avoid. Then came another act of sociality, the shotgun marriage of protons and neutrons in families of between two and ten.[17] These proton and neutron families were born of social urgency. Any neutron that didn't elbow its way into a particle cluster, any neutron that didn't join a particle gang, disintegrated after less than 10.6 minutes.[18] It underwent beta decay.[19] This was natural selection working on an instant scale. When it came to quarks and neutrons, only the social survived. And sociality is at culture's core.

When did another ingredient of culture— social memory, a memory that gives a foundation of knowledge, perception, and direction to an entire society—first arise? A firm answer is more elusive than you might think. Why?

For the first 300,000[20] years after the Big Bang, the cosmos was host to a massive social dance. Particle gangs moved at superspeed, colliding with each other like bullets smashing head to head, then bouncing away with ferocious velocity.[21] Astonishingly, the particles involved—particularly the protons—came out of each crash with all their mass and form intact. Was this act of identity-retention a primitive form of memory? Was it tradition arisen before its time?

Then another basic of culture emerged, mass behavior. Particle families ricocheted from one smash-up to another so quickly that the speed of serial ricochets defied belief. We call this form of superspeed bump-em-car behavior a plasma. But despite all the mayhem and non-stop crashes, the plasma showed a form of coordinated social behavior that defies belief. Elbow room between particle gangs was hard to find. Yet particle clusters in synchronized swaths that went from one end of the cosmos to the other bunched together tightly then parted again. They collaborated in a cosmos-spanning Busby Berkeley style of choreography. When they crowded together, these super-synchronized chorus lines formed the peak of a wave. When the cosmos-spanning chorus lines of particle gangs gave each other just a hint of elbow room, they formed that wave's trough. These pressure waves[22] washed across the cosmos like tsunamis in the sea. The physicists who discovered these early surges and swells used another metaphor to describe them—the metaphor of music.[23] Thanks to mega-mass behavior, thanks to social behavior on the grandest scale, astrophysicists say this early cosmos and its plasma rang like a massive gong[24]…or, to put it in the words of *Science Magazine*, "The big bang had set the entire cosmos ringing like a bell." [25] Thanks to mega-mass behavior, the particles of this cosmos rocked and rolled to their own self-generated beat.

A mere three hundred thousand years into the universe's existence, three primitive precursors of culture's components had emerged:

- sociality,
- a primordial form of memory,
- and coordinated mass behavior.

Had we arrived at culture yet? Not by a long shot. But the first hints of its rudiments arose an astonishingly long time ago.

Remember, culture's most crucial substrate is sociality. And sociality still had a few more surprises up its sleeve before it would cough out culture.

Three hundred thousand years ABB (after the Big Bang) there came another mass astonishment, another radical act of sociality—The Big Break. The particles in the plasma slowed down (we call that deceleration "cooling"), separated, and gave each other more space.[26] But more space did not mean solitude…it did not mean time off from social gatherings. In fact, it meant the very opposite. Puny particles called electrons discovered for the first time in their 300,000-year existence that they were not satisfied on their own. They had an electromagnetic hunger, an electromagnetic craving for a sort of sociality this universe had never known. But there was another surprise in the offing. The **protons** at the heart of particle families discovered that they, too, felt they were missing something. They discovered that they, too, had an electromagnetic longing at their core.

The upshot of these longings in the hearts of particles was shocking. If you picture a proton as the size of the Empire State Building, an electron is so small you can hold it in your hand. Compared to the Empire-State-Building-sized proton, an electron is the size of a baseball. Or, to put it differently, a proton is more than 1,842 times as massive as an electron.[27] So if you and I had been around to bet on the outcome of protons' and neutrons' new electromagnetic lusts, the **last** thing we'd have guessed is that these social drives would bring electrons and protons together in tight synergies. And, even if one proton **did** manage to hook up with an electron somewhere in this cosmos, we'd have considered it a freak event, a fluke, something that could not and would not ever happen again. But we'd have been dead wrong. Three hundred thousand years ABB (after the Big Bang), electrons discovered that their needs fit the longings of protons perfectly. No matter where the electron was and no matter what its life history, pick any proton in this universe at random, flip it an electron from anywhere you please, and the fit would be more precise than anything even the makers of the ultimate hi-precision scientific device, CERN's Large Hadron Collider,[28] have ever been able to achieve.

In a paper in the physics magazine *PhysicaPlus*—"The Xerox Effect: On the Importance of Pre-Biotic Evolution"[29]— I called this sort of thing manic mass production and supersynchrony. Supersynchrony refers to those landmark events in which the same thing happens at the same time all across the face of the cosmos. Supersynchrony was at work when roughly 10^{88} nearly identical quarks precipitated at precisely the same time from the space-time manifold, from a spreading sheet of speed. Supersynchrony was at work when that vast mob of quarks appeared in every nook, cranny, and wrinkle of this huge unfolding universe.

On the other hand, the amazing number of precipitations of quarks from mere speed is manic mass production. Yes, there was variety among the first quarks. There were between eight and 18 species.[30] But only eight to eighteen in a cosmos that is supposedly random? And roughly 10^{87} identical copies of each quark type? Manic mass production on a scale that defies belief! Impossible. At least impossible in the eyes of our current assumptions about randomness, our notion of six monkeys at six typewriters randomly typing the works of Shakespeare. And randomly pecking out the evolution of the cosmos. But it may be time to toss the current concept of the random away. It may be time to rid ourselves of the six monkeys with six typewriters and to realize that this universe runs like a railroad train. It has a lot of freedom, yet it is rigidly constrained. A locomotive has many routes it can take to get from New York to LA, but it cannot leave the rails. It cannot plow through pastures of corn, through houses, under oceans, through wormholes, or fly the Jet Stream. A train—and our universe—have a limited number of paths they can take.

Have other instances of supersynchrony and manic mass production appeared in the evolution of the cosmos? Yes. It's happened at every turn, as we're about to see. What do supersynchrony, manic mass production and railroad trains have to do with culture and the cosmos? What do they have to do with an evolutionary imperative to take ecosystems off this fragile planet and to seed them in space? Far more than you might think.

In the Big Break approximately years 300,000 ABB (After the Big Bang) the new proton, neutron, and electron teams—atoms of helium, hydrogen, and lithium—discovered yet another social gatherer, a force of mass attraction that had never manifested itself in quite this way before. We call it gravity. And over the next 200 million years or so,[31] this subtle, terribly weak force, gravity, created entirely new forms of sociality. Gravity swept loose atoms into new herds and flocks—into wisps of gas.[32] Those gas wisps kicked off the era of the Great Gravity Crusades. Wisp battled wisp to see which could use its gravity to dragoon the most new atoms. When one wisp battled another, the larger always won, cannibalizing its competitor.[33] In the end the call of gravity that tugged atoms together led to the formation of two vast and astonishing new things—galaxies and stars.[34]

Once again, supersynchrony and manic mass production were king. Galaxies and stars assembled by the billions, and all were pretty much the same.[35] Yes, there was far more variation than there had been among quarks, protons, and atoms. And the simultaneous timing was not so exquisitely precise. But when you leave Penn Station in Manhattan, there are only two directions you can take—west to tunnels under the Hudson River or east to tunnels under the East River.[36] As you get farther from Manhattan, there are more switchpoints you can follow, and your options open up, they multiply. The farther this cosmos got from its first simple laws—the law of speed, the law that converts speed to matter, and the laws of attraction and repulsion—the looser the mesh of limitations that held this cosmos in its weave. The farther this unfolding universe got from the first flick of the Big Bang, the more freedom it achieved.

Roughly 20 to 30 million years after the Big Break the biggest of the stars, the grandest mega-mobs of atomic nuclei spawned by gravity from one end of the universe to the other, once again underwent something new. And these mega-mobs, high-mass stars, did their gruesome new trick pretty much at the same time.[37] They went nova! They collapsed upon themselves, dying with screams of photons, streams of light, and with groans of outpoured energy. It was a cosmic massacre. But it was also supersynchrony.

Nothing good should come from death. But in this cosmos, something of value usually does. The gift of the death of the first massive stars was a new form of supersynchronous social assembly, a gift of the social pressures in the crumpling stars' crunched and tortured hearts.[38] Until now there had only been three forms of atoms—hydrogen, helium, and lithium. But as the stars imploded, as they caved in upon themselves, the resisting nuclei of hydrogen, helium, and lithium atoms were shoved violently together, mashed in masses with a force that overrode the powers with which these nuclei normally maintained their identity. The results were four new forms of proton-neutron teams. Four new elements: iron, carbon, nitrogen, and oxygen.[39]

In a random universe, we would have expected a million new forms of atoms or more. But this is a cosmos with railroad constraints, a cosmos where supersynchrony and manic mass production reign. Hence the number of new forms of atom-cores was pathetically tiny by the standard of six-monkey-at-six-typewriter randomness. And thanks to manic mass production, the number of precise duplicates of these four new atomic nuclei was vast.

Once again we had the primitive precursors of culture. Carbon, which was crunched together in the heart of the first generation of dying stars,[40] is a collective, a team, a tight-knit social gathering of 18 to 20 protons, neutrons, and electrons.[41] And it has a primal form of tradition and memory. You can run a carbon particle-team through a host of natural catastrophes, and the atom will go through only three minor changes. Those changes are called isotopes. But the carbon atom's basic identity, its coherence as a society with its own distinct characteristics, will stubbornly remain the same. Carbon will insist on remaining carbon. This is so close to culture and tradition that it's scary.

Which raises the big question once again. When did culture begin? When did evolution go from supersynchrony to the rise of collective tradition, collective innovation, collective differentiation, and the collective process that carries a group treasury of habits, attitudes, technology, and instructional stories from one generation to another down the line of time? Protons and carbon had a strange semblance of memory. So did stars and galaxies. Stars worked in pretty much the same way generation after generation. New galaxies assembled in forms that aped their elders. And there was something akin to tradition in the way that the first seven forms of atoms—hydrogen, helium, lithium, iron, carbon, nitrogen, and oxygen— continued to appear in era after era of cosmic change. There was even collective innovation, collective creativity. The second generation of stars, stars like ours, had new forms of atomic nuclei to chew on. And using those nuclei, they attained new powers. Inventive first-[42] and second-generation star-deaths mashed together roughly 85 new forms of atomic nuclei, 85 new elements from scandium and titanium to potassium and platinum.[43] So why isn't this culture?

Because the maintenance of old ways was only a semblance of tradition and memory. It was a precursor, but not the real thing. The maintenance of identity and of old ways of doing things—things like the particle-munch in the heart of a star and the evolution of spiral arms of galaxies—was a product of the cosmos' forces, formulas, processes, and shapes. It was the persistence of the natural equivalent of railway tracks—the laws of the universe—the cosmos' rigid constraints. Supersynchrony and manic mass production weren't culture. They weren't really memory. Then what's the difference between the persistence of the laws of nature and memory? And why does nature have laws, anyway?

A railroad train follows the same precise path thousands of other trains have taken. Why? Because the rails restrict its movement. The memory is not in the train, it's in the tracks. But the form of memory that would generate culture is a guidance system inside the train itself. It's an accumulation of lessons learned from experiences that have worked and experiences that haven't. And culture is something more. It's a story, a vision, a worldview that dictates a future path, a future path that may be utterly new, utterly old, utterly right, or utterly wrong. A culture is a memory that imagines futures and makes them real. It's an internal record of the past that steers us into the unknown of the next minute, the next decade, and the next century.

The next cosmic move toward culture should be described by a study physicists, astronomers, and cosmologists have begun but haven't yet named. Astrophysics has a field—a very small one—called nucleocosmochronology. Nucleocosmochronology is dedicated to fixing the dates for the rise of the 92 natural atomic nuclei and to pinning down key dates in the evolution of the cosmos.[44] It helps folks like me, multi-disciplinary theorists, paleopsychologists, the makers of cosmic time lines, and the tellers of the cosmos' stories. It promises to help us understand when the nuclei of critical atoms like chlorine, calcium, sodium, potassium, and phosphorus first appeared.

There's need for another science to complement nucleocosmochronology. It's moleculocosmochronology, a study that establishes the dates at which the first molecules appeared.[45] Like the quark trios that make protons and neutrons, and like atoms, galaxies, and stars, a molecule is a social group, a coalition of atoms with its own distinct identity. One of the most common molecules found in space, for example, is hydrogen cyanide. Hydrogen cyanide is an atomic trio, an atomic three musketeers. It's a tightly-knit lineup of one hydrogen atom, one carbon atom and one nitrogen atom. The carbon atom at hydrogen cyanide's center holds the hydrogen atom to one of its sides and locks the nitrogen atom to its other side, as if it had linked elbows with each of its two partners to hold them together as an unstoppable team. But astrochemists and molecular astrophysicists haven't yet pinned down the date of hydrogen cyanide's first appearance in this cosmos.[46]

When the number of atoms in a molecule climbs higher, our ignorance becomes worse. As Jan M. Hollis of the NASA Goddard Space Flight Center in Greenbelt, MD said in 2004, "At present …there is no accepted theory addressing how interstellar molecules containing more than 5 atoms are formed."[47]

We do know this. Carbon was the great seductress, hostess, and mix-mistress of the new element brigade.[48] And carbon's talent for introducing atoms to each other then hosting them as they gelled in stable families resulted in yet more supersynchrony. The result defied belief. It was the manic mass production of biomolecules. These carbon-based atom-teams arose in hot clouds of interstellar gas,[49] in cold clouds of interstellar gas,[50] in spicules of interstellar ice,[51] in the shrouds of dying stars,[52] in comets,[53] in meteorites[54] and in just about everything in between.[55] Today, ten percent of the volume of interstellar ice grains is composed of biomolecules.[56] As of 2000, we'd detected 120[57] forms of molecules in space.[58] One hundred of them were organic.[59] A mere 120 early molecules in a universe of six-monkey-and-six-typewriter randomness does not compute. The number should be in the billions. But one thing we know for sure. Manic mass production and a loose supersynchrony once again ruled. The cosmos was still hurtling down the narrow railroad tracks of cosmic destiny. Biomolecules in space included carbon dioxide, carbon monoxide, methanol, ammonia polyols, dihydroxyacetones, glycerols, sugar acids, and sugar alcohols[60] (all of which swarm together in a lipid sack when exposed to water…more about the critical importance of these lipid sacks to culture later).[61] And these molecules were all over the place.

The dates of molecular evolution may remain obscure, but the emergence and complexification of molecules set the stage for culture. They set the stage for the Big Belch—the emergence of REALLY complicated molecules. And they set the stage for those really big molecules' progeny, living creatures like you and me. The date of the Big Belch was far earlier than you might imagine. It was less than ten billion years ABB (after the Big Bang),[62] just a tad more than two-thirds of the way into this cosmos' existence.

Supersynchrony suggests that the Big Belch happened on planets scattered across the length and breadth of the universe.[63] Manic mass production hints at the very same thing. But the only planet we are sure the Big Belch occurred on is ours, Mama Earth.

In the Big Belch, sociality went big time in a whole new way. First, this planet began its own gravitational social gathering process, its kidnap, capture, recruitment, and massing of matter from the shards of a newly-ignited sun.[64] Then came the second stage of moleculogenesis.[65] Massive teams of molecules in the deeply buried water slicks, underground water pockets, above-ground puddles, and seas of this early world wove the walls of the lipid envelopes we met a second ago, envelopes surrounding a roped-off pool of water, a microscopic inner sea. What clues hint that these envelopes were among the first mega-projects produced by the Big Belch, produced by the second-stage of moleculogenesis? Take a chunk of the Murchison meteorite. Grind it up. It contains the simple biochemicals found all over the cosmos, simple molecules wrapped around the great atomic introducer, seducer, and recruiter, carbon.

Slip the powdered bits of the Murchison meteorite into water, and the social gathering of simple biomolecules begins. Your water is rapidly filled with tiny bubbles, sacks of water surrounded by a 360-degree mesh, water balloons held together by the waterproof envelope of an interwoven[66] molecular mega-community.[67] We call that self-woven bag—that microscopic capsule of molecular fabric— a “membrane”. And membranes—bio-envelopes—produced protective play-pens for more molecular socializing. Far, far more.

A mere 9.9 billion years after the Big Bang, the molecular sociality of the Big Belch took advantage of membranes and went whole hog into moleculologenic overdrive, spitting out molecules that were enormous—chain-ganging as many as 62 million atoms into a single molecular strand.[68] Supersynchrony and manic mass production also went into overdrive, apparently producing the same massive atomic communities—the same mega-molecules—all over this planet’s face. And those massive atom-teams soon formed their own social alliances…alliances driven by something very new, culture. Culture began when these mega-teams of atoms developed internal memory,[69] braided new strategies into their molecular strands, kept the strategies that worked, reproduced them in multitudes, and discarded or packed away in the cold storage of “junk DNA” the strategies that failed. It sometimes took storing five failed strategies to construct the mega-strategy from which a breakthrough would be made.[70]

These huge new atom communities were RNA and DNA. RNA and DNA were social as could be. They used membranes as fortifications, no-go zones, corrals within which RNA, DNA, and their membrane-weaving partners could maintain a specialized mini-sea, a Jell-O or Gatorade rich in vitamins, organic molecules, enzymes,[71] sugars, carbohydrates, fatty acids,[72] and proteins.[73] ^^

The Big Belch had produced cells. And each of these cells was a working community of 10^{11} atoms[74]—a hundred trillion atoms combined to pursue a highly complex common purpose. But, more important, a hundred trillion atoms with a heritage passed on from mother to daughter, a past recorded in a literal inner-circle, an interior ring of genes.[75] A hundred trillion atoms with the ability to evade danger and to find food. A hundred trillion atoms with the ability to make future predictions based on an accumulated data base, the store of information that gene-strings cadge, corner, and maintain. [76] And a hundred trillion atoms with the ability to rejigger their collective memory's instructions on how to make the next move. A hundred trillion atoms with the ability to reprogram their instruction-set, their genome.[77] In other words, these clusters of a hundred trillion atoms contained the first molecules in the history of the cosmos to have the advantage of culture. But how did these culture-driven molecular mobile cities manage to skyhook themselves into new niches, to turn new wastes into food, and to gain new abilities? The answer, once again, is sociality.

No cell is an island. The ancestral cells we're talking about were bacteria. And no bacterium can live alone. Put a single bacterium in solitary confinement. Give it its own petri dish with agar spread across the bottom as food. The bacterium will not become pensive and reflective, enjoying its solitude. It will do the opposite. It will split over and over again, giving birth to a huge bacterial family.[78] And each new family member, in turn, will multiply like crazy to conquer more of the agar.[79] Solitary bacterial cells create communities of unbelievable size around themselves in a very short amount of time. Give them a few weeks and the total bacterial tribe in your petri dish will have a population of 7 trillion[80]—more than all the humans who have ever lived. And that supersized society will not be a disorganized mass of individuals.[81] Far from it. Individual bacteria share their information with a complex chemical language.[82] The result is an information-processing web, a massively parallel-processed computation-and-connection machine, what one leading researcher on this form of social integration among bacteria, Eshel Ben-Jacob of the University of Tel Aviv, calls a "creative web."[83] Your bacterial culture, the bacterial mega-society in your petri dish, will be a research and development machine, a collective intelligence. According to Ben-Jacob it will be capable of spotting problems and working to solve them, often producing solutions this cosmos has never previously seen. And at the heart of that collective expansion-and-innovation web will be, guess what? A culture.

A culture complete with monuments, with pyramids. The bacterial colonies of the first 3.5 billion years of life have left us their architecture, their massive public works projects. They're called stromatolites.[84] Stromatolites are stone structures the size of your mattress, stone monuments poking from the shallow seas around Australia and fossilized in the rocks of Michigan. How are they produced?

They're created by bacterial teams contributing to a massive multi-generational enterprise. A colony of bacteria exudes a gooey foundation on which it sits. Each bacterium sucks a key portion of its food—carbon dioxide—from the shallow waters of the sea. This triggers the precipitation of particles of calcium carbonate—grains of limestone—from the water. The falling microbits of stone pile up in the glue-like base of the bacterial colony.[85] The next bacterial colony lives on top of this ultra-thin limestone residue, and in its lifetime leaves a second slick of lime. Millions or trillions of colonies later, those thin slicks of limestone add up. They create a monument nearly as big in comparison to a single bacterium as the moon is to you and me. Quite an accomplishment for creatures with collective computational powers and creativity, but without brains.

Bacteria were the founders of culture. But they were not the only cultural creatures to appear in the next 3.5 billion years of life's evolution. They were not the only culture-gifted children of the Big Belch. In 1983, John Tyler Bonner wrote a classic book on *The Evolution of Culture in Animals*.[86] Bonner revealed culture in myxobacteria, slime molds, birds, whales, social insects, and chimpanzees.
^^
Then came human culture, another multi-generational, multi-layered group project that accumulated memories, habits, and methods of turning new niches of barrenness into a paradise. We were born one of the most pathetic creatures this Earth has ever seen. Other animals were birthed with biological equipment for thermoregulation,[87] for making it through sizzling heat and biting cold. They were born with fur coats. Not us. We were born as naked as hairless mole rats, like pieces of meat tossed to the crocodile jaws of the elements. Like our cousins, the chimps[88] and cheetahs, we were born with a lust to eat meat. We needed this high-protein diet to fuel our energy-hungry big brains.[89] But we were born without a stitch of hunting equipment. We emerged from the womb without fangs and teeth. We were born without the four legs that give horses, gazelles, and lions their speed.

We were also born without the equipment to be successful vegetarians. Our cousins, mountain apes,[90] had huge bellies capable of breaking down the cellulose fortresses that protect the cells of leaves. We, on the other hand, had relatively tiny tummies[91] that didn't stand a chance against the vegetable roughage, the greenery that surrounded us. Culture was our only means of rescuing ourselves. First we invented artificial fangs and teeth 2.5 million years ago.[92] We invented the Oldowan stone tool kit.[93] Then we tamed fire[94] and invented cooking,[95] a way to predigest our meals so that our compact digestive system (and its bacterial partners)[96] could extract the fuel from the toughest foods. The small abdomen that cooking made possible gave us a mobility our knuckle-walking cousins had never possessed.[97] According to evolutionary neurobiologist John Skoyles, it also gave us the swiftness of marathon runners.[98] We couldn't outrace a zebra or an antelope, but we could outlast it in a long-distance marathon run,[99] then could take advantage of the animal's fatigue to move in for the kill. What's more, we were the first—and so far, the only—species able to hurl a stone at high velocity with perfect aim.[100] We were pitchers par excellence. We could literally knock a bird out of the sky with a stone[101] or kill a fast-moving rat or rabbit with an overhand toss.[102] Which meant we could hunt small game in ways that claws and fangs had never made possible.

Somewhere along the line we also invented clothing[103] and marched off to the far north,[104] equipped to shield ourselves from winter snow, and ice. We also invented architecture during the ice ages, building palaces with frameworks of mammoth tusks and mammoth ribs and an outer skin made of mammoth hides.[105] And we invented ways to feed two needs that obsess us in a manner few animals will ever know—identity and vanity.[106] We invented makeup 280,000 years ago[107] to differentiate my tribe from yours and to let you compete for attention with your tribemates, too. We invented long-distance trade[108] 140,000 years ago[109] so that folks in the interior of a continent could show off by wearing jewelry made of sea creatures' shells[110] and so that coastal dwellers could make tools of obsidian mined far inland. We invented beads[111] to let each other know who was on top of the tribe's wealth and who was not.[112] Finally, ten thousand years ago, we invented agriculture[113] and cities.[114] Cities gave birth to subcultures,[115] and the competition between human cultures and subcultures went into overdrive.

Without material breakthroughs, human culture would never have achieved its current heights. In fact, without our host of material inventions—the spear, the fireplace, the coat, the boat, the brick, the book, and the laptop—it's very unlikely that we humans would have survived. But culture was a dance between material innovations and innovations of the mind. Human culture layered new concepts, new languages, and new forms of data-processing, data-storing, worldview-making, scenario-creating, and future prediction. Human culture worked with the multi-generational stubbornness of the bacteria that built stromatolites. But instead of constructing physical monuments the size of moons, human cultures built new mind tools—concepts, metaphors, religions, stories, creation myths, tales of legendary heroes, sagas of triumphs and defeats, and entire worldviews[116]—mind tools that from the very first were celestomanic—sky-obsessed, turned to the heavens and the stars. These were new mind tools that could decipher the Earth below and the cosmos slowly wheeling above our heads.

One hundred and twenty five thousand generations of this layering have made us conscious…and have misled us into a peculiar arrogance. We think that we have reshaped this planet more than any creatures that have come before. We think that we have plundered the pitifully small pool of resources on this Earth and now must make sacrifices to appease a nature angered by our transgressions. We are wrong. Very wrong.

Bacteria nearly two billion years ago[117] utterly polluted this planet's atmosphere by farting out a toxic gas that seemed to threaten all of life. That gas was oxygen.[118] And yet other bacteria were the ones who learned to turn this poison to food and fuel.[119] They were the ones who learned to recruit the uncountable molecules of a poison into biomass.

The mud that covers the bottom of the sea is not just a product of inanimate nature.[120] It is a massive desecration of 70% of this Earth's early rocky surface,[121] a fertile sludge generated by the burrowing and swimming creatures of the sea.[122] It is the recruitment of gazillions of inanimate atoms into the grand project of biomass.

Microbes long ago raped the naked Earth above the seas, piercing its cloak of stone.[123] They produced chemicals that turned much of the planet's rock into powder,[124] spat out mineral particles from which new rocks would be made, and utterly reworked the native stone of this planet. Then plants dug their roots into microscopic cracks and split the virgin bedrock.[125] If Charles Darwin is right, every fruitful field now covered with soil was the product of a massive landscaping effort left to us by millions of generations of earthworms who "sinned" against nature by doing plastic surgery on our pristine planet's face.[126] The earthworms turned jagged outcrops and crevasses into gentle hills, slopes, and valleys. We use the worms' violation of Mother Nature to grow our plants and we worship the worms' legacy— rainforests and greenery.

Meanwhile bacteria have continued to outdo us in the research and development business, constantly remaking this rocky orb. They profane the planet by following nature's imperative for the grand experiment of life—take as many inanimate molecules as you can grab and press-gang them into the family of cells and DNA. Be fruitful and multiply. Turn poisons into delicacies and barren wastes into candy. Be consumerist as hell. Be materially rapacious. Make as much of this inanimate globe as you can into biomass.

What does this mean for you and me? What does it mean for the culture of human beings? Our culture is one among many this planet has spawned. But we think our culture is unique. And it is. Our culture is built on brains and on the passions of the hypothalamic-pituitary-adrenal-gonadal axis. Our culture is built on emotion, reason, and, literally, balls and guts. As a result, our culture froths with poetry, music, story-telling, technology, high aspirations, self-hating philosophies, and consciousness.

Our culture is also built on something no bacterium or chimp can conceive. It's built on an ancestor worship[127] that keeps our ancient trail of insights alive for hundreds of generations. We worship ancestors more than we know. In science, we invoke their names to validate our scientific claims. We refer to Plato, Aristotle, Newton, Darwin, and Einstein. We do it in our journal articles. We do it in our lectures and in our conventions. We do it all the time. In political life, we invoke our founding fathers—Jefferson, Washington, Benjamin Franklin and Alexander Hamilton. Islam invokes the memory of Mohammed and has produced tens of thousands of pages recording nearly every moment of his life.[128] Buddhism is built on the memory of Siddhārtha Gautama, the Buddha.[129] And anti-globalism and anti-capitalism keep alive the spirit of the French Revolution, Karl Marx, and Michele Foucault. The result is a layer-upon-layer crepe-cake of thought-tools that builds the way that bacterial stromatolites rise from the bottom of the sea and reach for the sky. But this multi-layered monument exists in imagination and achievement. It exists as a product of human minds.[130]

What can our culture—with these unique powers— do for the 3.85 billion-year experiment of the bioprocess? What can it do for the family of cells and DNA? What can it do for the mega-project of life? What, if any, is our mandate from this cosmos' history?

Our universe has shown a remarkable ability to reinvent itself and to create radically new forms—quarks, protons, galaxies, and stars—without culture and without human beings. Then the universe has used these new creations to create even more. As incarnations of nature, as the most complex forms of social dance protons have yet conceived, it is our obligation to contribute to this reinvention, to this production of massive surprises and of enormous change.

First off, we are NOT running out of resources. We are running out of ingenuity. We are using less than a quadrillionth of the resources of this planet. Geomorphologists point out that when you look at the Earth from space, "few if any natural landforms on Earth bear the unmistakable mark of life."[131] There is 1.097 sextillion cubic meters of rock, magma, and iron beneath our feet. (1,097,509,500,000,000,000,000[132]) That's over a sextillion-cubic-meter stock of raw materials we haven't yet learned to use. We haven't yet learned to turn that sextillion-cubic-meter stockpile into fuel, food, or energy. We haven't yet recruited it into the clan of biomass, into the family of DNA. We haven't yet pulled it into the enterprise of life.

Is there any indication that we could or should transform more of this material into biomass? Yes. The first clue comes from our clever relatives bacteria. Two miles beneath your feet and mine even as we speak, bacteria are turning granite into food and fuel, into substance for the grand project of biomass.[133] Anything bacteria can do, we can do better.

The second clue? We are the only species that can take the DNA-and-cell experiment off this planet, off this one pitiful and fragile ball of Earth. We are the only species that can plant biomass on other planets and moons in this solar system. We are the only species that can carry life to other stars and galaxies. And taking life beyond the Earth is an absolute necessity. Why?

The next mass extinction—the next great climate catastrophe— is inevitable, no matter how many Kyoto treaties, carbon sequestration schemes, and heroes of sustainability like Al Gore we have. Let's get to the bitter bottom line. There have been roughly 142 mass extinctions on this globe.[134] That's one species apocalypse every 26 million years.[135] What's more, carbon dioxide levels in our Earth's early atmosphere were 100 to 1,000 times[136] what they are today.[137] And there were no smokestacks or tailpipes anywhere in sight. In our 226 million-year[138] sweep around the center of our galaxy,[139] we accumulate 30 million kilograms of space dust per year. Every 100,000 years we whiffle through a cloud of interplanetary powder that **triples** that amount.[140] These dust immersions radically change the climate on the surface of our little sphere. And every 143 million years we plow through a spiral arm of our galaxy and hit a patch of cosmic rays that plunges us into an ice age.[141]

But there's more. There have been 60 ice ages in the two million years[142] since *Homo habilis*[143] began the trek that led to the evolution of you and me. What's more, in the last 120,000 years, the era of us physically modern men and women, us *Homo sapiens sapiens*,[144] there have been 20 global warmings,[145] hothouse conditions in which the planet's temperature has shot up between 10 and 18 degrees in a mere twenty years or less.[146] And that is just the beginning of the list of Mother Nature's atrocities. The sun itself has set us on the path to a slow boil. Good old sol is now 43% brighter—43% hotter—than it was when the Earth began.[147] Yet Earth has been in danger of freezing like an iceball over and over again[148] and has spent the last 420,000 years[149] in an ice age that only stopped for a brief pause roughly 12,000 years ago, when we humans were released from the deep freeze and began the steps that would lead to the invention of agriculture and cities, both of which we concocted roughly 10,000 years ago.[150]

Just to show how many natural flukes can resculpt our weather, until 10,000 years ago the Gulf Stream shifted its route every 1,500 years,[151] leaving former warm areas in the cold, and making former frigid zones semi-tropical. Then there's the Milankovich Effect, an eccentric wobble (a precession) in our planet's rotation around the sun that resculpts our climatic patterns every 22,000, 41,000, and 100,000 years.[152]

The climatic stability we think is natural is not.[153] It is a 12,000-year-long oddity, a total departure from Mother Nature's norm.[154] Unless we learn far, far more about meteorological engineering than we know today, the relatively stable weather we've bathed in since the departure of the last ice age 12,000 years ago will someday change entirely. Carbon sequestration may well be our first attempt at macro-meteorological tinkering. And it may lead to far more sophisticated ways to control our climate. But we have to ditch the fantasy that every climate glitch is our fault and that we must atone by shunning consumption, by sacrificing to the planet, and by making Mother Nature happy. Mother Nature's way is instability and catastrophe. She killed off stars. And she has killed off more species than we can count. Mother Nature, to quote a chapter title from my book *The Lucifer Principle: A Scientific Expedition Into the Forces of History*, is a "bloody bitch."[155]

We are a hydrophilic species. We are water lovers. Sixty percent of the humans on this globe live in coastal areas.[156] As Plato said, we are dotted like frogs around a pond.[157] And every coastal city we prize, from New York to Shanghai, will someday end up under the sea or on a mountaintop. That will happen with or without our carbon emissions. It's happened to many a water-loving species before us. That's why we find the fossils of sea creatures on mountain tops. The message? Without making some very big moves, all of us coastal frogs will someday either find ourselves far too high and dry or we will drown.

Mother Nature and the evolutionary process have provided a solution to the certainty of catastrophe. For 3.85 billion years, the imperative of biomass has been to accessorize the standard backbone of life[158]—the DNA-cell system—with as many ways of making a living, of consuming the inedible, of crawling into crevasses and crannies, and of soaring to new heights as it can. With that trick, the family of DNA has ensured that when the next big mass extinction hits, some life forms will be stripped away, but other of life's experiments, her variations on her Big Belch theme, will survive.

Bacteria are the ultimate survivors, the ultimate evangelists preaching through their actions the imperatives of evolution, the commandments of the cosmos, and the obligations of life. Lesson number one from bacteria is this. Without consumption, there would be no ecosystems. There would be no life. A bacterial colony expands by guzzling the fuel of photons, by harnessing inanimate chemistry, and by stitching lifeless atoms of nitrogen, hydrogen, and carbon into the molecules of proteins and sugars, into the weave of cell walls, into the braids of genes, and into the soup of protoplasm in between. A bacterial colony expands by recruiting, seducing, and conquering as many inanimate molecules as it can, bringing them into the family of biomass, the family of life. It expands by inventing new ways to consume.[159]

Bacterial lesson number two. Carve out as many new niches as you can. Race with all your might and creativity to outwit the next catastrophe, nature's next mass extinction. As we've mentioned, bacteria have invented ways to flourish in the toxic bath of oxygen that drowned this planet roughly two billion years ago.[160] They've learned to flourish where there is no oxygen at all.[161] They've invented ways to be fruitful and multiply eating the steel of oil pipelines[162] and the metal and PVC plastic[163] in the plumbing of skyscrapers.[164] They've invented ways to munch the most abundant metal in the crust of the Earth, aluminum,[165] and to turn it into bio-stuff. They've created techniques for living in plumes of water with a searing 120 degrees of heat and to press-gang inanimate sulfur atoms into the metabolic processes of life[166]. They've pioneered ways to thrive in the radioactive cooling pools of nuclear plants.[167] They've shown that in all probability they will take the carnage left by a nuclear Armageddon, eat it, and turn it into yet more mega-teams of innovators and of micro-inventors—more bacteria.

But that is the merest hint of bacteria's obsessive imperative to find new niches for life. Between fifty and five hundred trillion bacteria are in your throat and gut right now.[168] They've worked out a deal that makes you a niche, a portable home, and a gatherer of their groceries. The bacterial colonies in your throat defend you from hostile microorganisms,[169] and the bacterial colonies in your stomach and intestines digest much of your food for you. All you have to do is give them a nice, warm place in which to live. They've worked out a similar deal with migrating water fowl, who fly bacterial colonies thousands of miles, allowing them to spread intercontinentally.[170] Bruce Moffett, a microbiologist at the University of East London, even suspects that bacteria have worked out ways to fly high, thrive in clouds, and to make the weather they like the best.[171] The result? Bacteria have survived every mass extinction with which this planet has threatened to wipe out biomass.

Now the trick is to spread this invention of new niches, this recruitment and radical upgrade of dead atoms, this next step in evolution that we call life, beyond one tiny, fragile nest. The biggest unfilled niche for life exists above our heads.

There's a simple trick nature has taught us via birds. There are more than twice as many bird species as species of mammals.[172] The lesson? Those who fly find or create more environmental pockets of riches than those who remain earthbound.

We are the only species on the face of this planet who can fly beyond the atmosphere. We are the only beings whose culture has created spaceships. We are the only life forms who have walked on the moon. We are the only bio-mechanisms who can take ecosystems to the planets and the stars.

Our mission, should we choose to accept it, is to innovate our way around every climatic catastrophe nature throws our way. It is to spread the products of the Big Belch, to expand life's unique form of manic mass production and supersynchrony. It is to find more protective niches—niches in this solar system and beyond—for the family of cells and DNA. Our evolutionary mandate is to give life a shot at pulling all of this cosmos into the evolutionary process. Our evolutionary mandate is to recruit all of this universe into the process we call nature, the process we call culture, the process we call ecosystems, the process we call life.

—end—

[1.] The Comm Tech Lab and the Center for Microbial Ecology at Michigan State University. *The Microbe Zoo DLC-ME Project*. Retrieved September 1999, from the World Wide Web http://commtechlab.msu.edu/sites/dlc-me/zoo/.

[2] Susan L. Hurley, Nick Chater. Perspectives on Imitation: From Neuroscience to Social Science Cambridge, MA: MIT Press, 2005: p. 150.
[3] S. McBrearty and A. S. Brooks. The revolution that wasn't: a new interpretation of the origins of modern human behavior. Journal of Human Evolution, 39, 5, 2000: pp. 453-563. R. G. Klein, The Human Career. Chicago: University of Chicago Press, Chicago, ed. 2, 1999.
[4] S. McBrearty and A. S. Brooks. The revolution that wasn't: a new interpretation of the origins of modern human behavior. Journal of Human Evolution, 39, 5: 2000: pp. 453-563. R. G. Klein, The Human Career. Chicago: University of Chicago Press, Chicago, ed. 2, 1999.
[5] Luis Benítez-Bribiesca. The Biology of Music. Science Magazine. June 29, 2001: Vol. 292. no. 5526: pp. 2432 – 2433. Josie Glausiusz. The Genetic Mystery of Music: Does a mother's lullaby give an infant a better chance for survival? Discover Magazine, Vol. 22 No. 8, August 2001.
[6] Alexander Marshack. "Evolution of the Human Capacity: The Symbolic Evidence." Yearbook of Physical Anthropology. New York: Wiley-Liss, 1989. Alexander Marshack, "The Tai Plaque and Calendrical Notation in the Upper Palaeolithic." Cambridge Archaeological Journal. April 1991: p. 25. Alexander Marshack. "On 'Close Reading' and Decoration versus Notation." Current anthropology, February 1997: p. 81.
[7] H. Valladas, J. Clottes, JM Geneste, M.A. Garcia, M. Arnold, H Cachier, N. Tisnérat-Laborde. Palaeolithic paintings. Evolution of prehistoric cave art. Nature. 2001 Oct 4; 413(6855): p. 479.
[8] Sally McBrearty, Alison S. Brooks. The revolution that wasn't: a new interpretation of the origins of modern human behavior. Journal of Human Evolution 39. 5 2000: pp. 453-563. Carl Zimmer. Great Mysteries of Human Evolution: New discoveries rewrite the book on who we are and where we came from. Discover Magazine, Vol. 24 No. 09, September 2003.
[9] Alan L. Deino, Sally McBrearty, Ar dating of the Kapthurin Formation, Baringo, Kenya. Journal of Human Evolution; January 2002, Vol. 42 Issue ½: pp.185-211.
[10] Lawrence S . Barham, Systematic Pigment Use in the Middle Pleistocene of South- Central Africa. Current Anthropology, Volume 43, Number 1, February 2002.
[11] James Harrod. Researching the Origins of Art. Religion, and Mind: Middle Paleolithic Art, Symbols, Mind
Retrieved from the World Wide Web April 25, 2004 http://www.originsnet.org/mindmp.html. Larry Barham. From art and tools came human origins. British Archaeology Magazine. Editor: Simon Denison Issue no 42, March 1999. Council for British Archaeology
Retrieved from the World Wide WebApril 25, 2004
http://www.britarch.ac.uk/ba/ba42/ba42feat.html. Robert G. Bednarik. The earliest known palaeoart. Retrieved from the World Wide Web April 25, 2004. First published in Vladimir Vasil'evich Bobrov (ed.), Pervobytnaya arkheologiya: chelovek i iskusstvo, pp. 23-31. Kemerovskii gosudarstvennyi universitet, Novosibirsk. Retrieved August 11, 2007, from the World Wide Web
http://mc2.vicnet.net.au/home/aura/shared_files/kemerovo.pdf
[12] Howard Bloom. "Manifesto for a New Psychological Science. ASCAP—Across-Species Comparisons and Psychopathology Society. Vol. 10, No. 7, July 1997: pp. 20-21, 27.
[13] Pennsylvania State University geoscientist James F. Kasting feels the consensus date for the origin of life on Earth is roughly four billion years. (James F. Kasting. "Planetary Atmospheres: Warming Early Earth and Mars." Science, 23 May 1997: pp. 1213-1215.) Evidence tends to pin the date to an undetermined period before 3.85 billion years ago. See: Heinrich D. Holland. "Evidence for Life on Earth More Than 3850 Million Years Ago." Science, 3 January 1997: pp. 38-39.; Norman R. Pace "A Molecular View of Microbial Diversity and the Biosphere." Science, May 2, 1997: pp. 734-740; S.J. Mojzsis, G. Arrhenius, K.D. Mckeegan, T.M. Harrison, A.P. Nutman and C.R.L. Friend. "Evidence for life on Earth before 3,800 million years ago." Nature, 7 November 1996: pp. 55 – 59. NASA News Releases. "96-11-05 When Life Began On Earth." Retrieved November 13, 1996, from the World Wide Web
http://spacelink.msfc.nasa.gov/NASA.News/NASA.News.Releases/
Previous.News.Releases/96.News.Releases/96-11.News.Releases/ 96-11-
05.When.Life.Began.On.Earth, January 1999. John M. Hayes. The earliest memories of life on Earth. Nature, November 7, 1996: pp. 21-22.

[14] Richard A. Kerr. Early Life Thrived Despite Earthly Travails. Science 1999 June 25; 284: pp. 2111 2113. M. Gogarten Boekels, E. Hilario, J.P. Gogarten. "The effects of heavy meteorite bombardment on the early evolution—the emergence of the three domains of life." Origins of Life and Evolution of the Biosphere, June 1995: pp. 251-264. Retrieved August 30, 2018, from the World Wide Web
http://www.springerlink.com/content/hl23380073722636/. Dana Mackenzie. "Moon-Forming Crash Is Likely in New Model." Science, 1 January 1999: pp. 15-16.

[15] Charles Seife. Breakthrough Of The Year: Illuminating the Dark Universe. Science 19 December 2003: Vol. 302. no. 5653: pp. 2038 – 2039. DOI: 10.1126/science.302.5653.2038.

[16] J. Allday. Quarks, Leptons, and the Big Bang. IOP Press, 1998. L.Bergstrom and A. Goobar. Cosmology and Particle Astrophysics. New York: Wiley, 1999. Jeremy Bernstein. An Introduction to Cosmology. Englewood Cliffs, NJ: Prentice Hall, 1995: pp. 12-14. Edward L. Wright. “Brief History of the Universe.” Astronomy Department, UCLA. Retrieved August 12, 2007, from the World Wide Web http://www.astro.ucla.edu/~wright/BBhistory.html. G.H. Hardy. Ramanujan: Twelve Lectures on Subjects Suggested by his Life and Work. New York: Chelsea, 1999.

[17] A family of two, a neutron and a proton, is deuterium. A family of ten, three protons and seven neutrons, is Lithium 7. Subir Sarkar. Big Bang Nucleosynthesis: Reprise. In L. Baudis. Dark Matter in Astrophysics and Particle Physics 1998: Proceedings of the Second International Conference on Dark Matter and Particle Physics, Heidelberg, 1998. Boca Raton: CRC Press, 1999: p. 108.

[18] Bruno Bertotti. Modern Cosmology in Retrospect. Cambridge: Cambridge University Press, 1990: p. 185.

[19] Michael Zeilik. Astronomy: The Evolving Universe. Cambridge: Cambridge University Press, 2002: p. 361.

[20] Ron Cowen. Sounds of the universe confirm Big Bang. Science News, April 28, 2001; Vol. 159, No. 17
Retrieved March 30, 2002, from the World Wide Web
http://www.sciencenews.org/20010428/fob3.asp

[21] Michael D. Lemonick. Echo of the Big Bang. Princeton, NJ: Princeton University Press, 2003: p. 205.

[22] Charles Seife. Breakthrough Of The Year: Illuminating the Dark Universe. Science 19 December 2003: Vol. 302. no. 5653, pp. 2038 – 2039. DOI: 10.1126/science.302.5653.2038.

[23] Christopher J. Miller, Robert C. Nichol, and David J. Batuski. Acoustic Oscillations in the Early Universe and Today. Science, June 22, 2001 292: pp. 2302-2303; [DOI: 10.1126/science.1060440]. Ron Cowen. Sounds of the universe confirm Big Bang. Science News, April 28, 2001; Vol. 159, No. 17
Retrieved March 30, 2002, from the World Wide Web
http://www.sciencenews.org/20010428/fob3.asp

[24] These oscillations, these acoustic waves, apparently continued rolling through the early cosmos for a full 400,000 years. George Musser. The Peak of Success. Scientific American, August 2001, Vol. 285 Issue 2: pp. 14-15.
Retrieved August 30, 2018, from the World Wide Web
http://ehostvgw6.epnet.com/ehost.asp?key=204.179.122.129_8000_-1525769105&site=ehost&return=n&custid=nypl&IP=yes&profile=web&defaultdb=aph

[25] Charles Seife. Breakthrough Of The Year: Illuminating the Dark Universe. Science 19 December 2003: Vol. 302. no. 5653, pp. 2038 – 2039. DOI: 10.1126/science.302.5653.2038.

[26] Bertram Schwarzschild. Cobe Satellite Finds No Hint of Excess In The Cosmic Microwave Spectrum. Physics Today, March 1990: p. 18. Retrieved August 30, 2018, from the World Wide Web

http://www.physicstoday.com/vol-43/iss-3/pdf/vol43no3p17_20.pdf.

[27] George Wald. "The Cosmology of Life and Mind." In New Metaphysical Foundations of Modern Science. Edited by Willis Harman with Jane Clark. Sausalito, CA: Institute of Noetic Sciences, 1994: 124-125.
[28] CERN. LHC—The Large Hadron Collider. Retrieved August 30, 2018, from the World Wide Web
http://lhc.web.cern.ch/lhc/
[29] Howard Bloom. "The Xerox Effect: On the Importance of Pre-Biotic Evolution" in PhysicaPlus, the online publication of The Israeli Physical Society. January 10, 2004. Retrieved August 30, 2018, from the World Wide Web
http://physicaplus.org.il/zope/home/en/3/mabat_bloom_en
[30] "quark." Encyclopædia Britannica. Encyclopædia Britannica Online, 2007. Retrieved August 30, 2018, from the World Wide Web http://www.britannica.com/eb/article-9062172.
[31] Some astronomers set the date of the first stars at 200 million ABB (after the Big Bang). Others pin the date of the first star formation to 400 million ABB. Ron Cowen. Beryllium data confirm stars' age. Science News, September 18, 2004. Retrieved September 30, 2004, from the World Wide Web http://www.sciencenews.org/articles/20040918/note11.asp. Cowen's article gives the date of 200 million years ABB. Dennis Overbye. Astronomers Find The Earliest Signs Yet Of Violent Baby Universe. New York Times, Friday, March 17, 2006: Late Edition - Final, Section A, Page 18. Overbye's article gives the date of 400 million years.
[32] Evan Scannapieco, Patrick Petitjean, Tom Broadhurst. The Emptiest Places. Scientific American, Oct 2002, Vol. 287, Issue 4. James Glanz. Astronomers See Evidence of First Light in Universe. New York Times, August 07, 2001. Retrieved August 13, 2007, from the World Wide Web
http://www.nytimes.com/2001/08/07/science/space/07DARK.html?pagewanted=print
[33] "The most widely accepted picture of how structure formed involves the idea of gravitational instability. A perfectly smooth self-gravitating fluid with the same density everywhere stays homogeneous for all time. But any slight irregularities (which always exist in reality) tend to get amplified by the action of gravity. A small patch of the Universe that is slightly denser than average tends to attract material from around itself; it therefore gets even denser and attracts even more material. This instability will form a highly concentrated lump, held together by gravitational forces." Peter Coles (1998). The end of the old model Universe. *Nature*, June 25, 1998, 393: 741 – 744.
[34] Berkeley University astronomer Hyron Spinrad refers to this process as "'the hierarchical merging of gas-rich systems." Hyron Spinrad. Galaxy Formation and Evolution. New York: Springer, 2005: p 42.
[35] Amanda Gefter. Scale in the universe. New Scientist, March 9, 2007. Retrieved August 13, 2007, from the World Wide Web
http://space.newscientist.com/article/mg19325941.600;jsessionid=OCFJLFLEGCNP
[36] Map of the tunnels exiting Pennsylvania Station, NY. From: Kenneth M. Mead. Inspector General. U.S. Department of Transportation, Office of the Secretary of Transportation. Letter to The Honrable Frank Wolf, Chairman, Subcommittee on Transportation and Related Agencies, Committee on Appropriations, United States House of Representatives. Conditions in the Tunnels below Pennsylvania Station. Dec 18, 2000. Retrieved August 30, 2018, from the World Wide Web
http://www.cartome.org/penn-tunnel-safety.pdf. Wikipedia. Pennsylvania Station (New York City). Retrieved August 30, 2018, from the World Wide Web
http://en.wikipedia.org/wiki/Pennsylvania_Station_(New_York_City) . Wikipedia. Pennsylvania Tunnel and Terminal_Railroad. Retrieved August 30, 2018, from the World Wide Web
http://en.wikipedia.org/wiki/Pennsylvania_Tunnel_and_Terminal_Railroad. Wikipedia. East River Tunnels. Retrieved August 30, 2018, from the World Wide Web
http://en.wikipedia.org/wiki/East_River_Tunnels
[37] Amy J. Berger. The Midlife Crisis of the Cosmos. Scientific American, January 2005.
[38] Robert Irion. The Quest for Population III. Science, 4 January 4, 2002: Vol. 295. no. 5552: pp. 66 - 67. DOI: 10.1126/science.295.5552.66.
[39] Timothy C. Beers.The First Generations of Stars. Science, July 15, 2005: Vol. 309. no. 5733, pp. 390 - 391. DOI: 10.1126/science.1114671. Iron, carbon, nitrogen and oxygen are the four

elements the author feels evolved from the first star deaths. But Beers cautions that, "Astronomers are uncertain which elements might form in these very massive stars during their explosive death throes, but current calculations indicate that they should eject large amounts of iron and only small amounts of carbon." Michael Shull and Fernando Santoro believe that the first generation of high-mass star deaths also produced silicon. Michael Shull and Fernando Santoro. Critical Metallicity of the IGM. Presented at First Stars III, Santa Fe, New Mexico, July 17, 2007. p. 4. Retrieved August 30, 2018, from the World Wide Web
http://www.lanl.gov/conferences/firststars3/abstracts_and_talks/m_shull_talk.pdf

[40] For more detail on how a dying star produces heavy elements like iron and carbon, see: Stephen James O'Meara. Deep-Sky Companions: The Caldwell Objects. New York: Cambridge University Press, 2003: p. 130.

[41] The Carbon Atom. Math and Science Activity Center—edinformatics.com. Retrieved August 30, 2018, from the World Wide Web
http://www.edinformatics.com/math_science/c_atom.htm

[42] David Arnett and Grant Bazan. Nucleosynthesis in Stars: Recent Developments. Science, Volume 276, Number 5317 Issue of 30 May 1997: pp. 1359-1362.

[43] For the standard view of nucleogenesis in second generation stars, see Henri Boffin and Douglas Pierce-Price, Fusion in the Universe: we are all stardust. Science in School. Retrieved August 30, 2018, from the World Wide Web
http://www.scienceinschool.org/2007/issue4/fusion/. Henri Boffin and Douglas Pierce-Price are with the European Organisation for Astronomical Research in the Southern Hemisphere, in Garching, Germany.

[44] "nucleocosmochronology is a good way to determine the time at which stars and galaxies were formed" Peter Coles, Francesco Lucchin. Cosmology: The Origin and Evolution of Cosmic Structure. New York: John Wiley and Sons, 2002: p. 84. "In effect, nucleocosmochronology is a way of dating the creation of the heavy elements" Richard M. West. Highlights of Astronomy, International Astronomical Union General Assembly, International Astronomical Union. Published 1983, Dordrecht, Holland: Reide: p. 243. Donald D. Clayton. Galactic Chemical Evolution and Nucleocosmochronology: A Standard Model. in Nucleosynthesis : Challenges and New Developments. Edited by W. David Arnett and James W. Truran. Chicago: University of Chicago Press, 1985: p.65.

[45] The best approximation to moleculocosmochronology we have is Astrochemistry and Molecular Astrophysics—two fields that search for molecules in space, theorize about how those molecules formed, but don't pin down when. See: David Curtis and Julian Sonin..What is Astrochemistry? Expo/Science & Industry/Whispers From the Cosmos. Cyberia. National Center for Supercomputer Applications at the University of Illinois in Urbana-Champaign. 1995. Retrieved August 30, 2018, from the World Wide Web
http://archive.ncsa.uiuc.edu/Cyberia/Bima/astrochem.html. Also see: Centre for Astronomy, NUI Galway. Star Formation & Astrochemistry Group. National University of Ireland, Galway. Retrieved August 30, 2018, from the World Wide Web
http://astro.nuigalway.ie/research/starformation.html#astrochemistry For a good example of Astrochemistry, see: Lucy M. Ziurys. The chemistry in circumstellar envelopes of evolved stars: Following the origin of the elements to the origin of life. Procedings of the National Academy of Sciences, August 15, 2006, vol. 109, no.33. Retrieved August 30, 2018, from the World Wide Web
http://www.pnas.org/cgi/reprint/103/33/12274.pdf

[46] For the possible role hydrogen cyanide may have played in the evolution of life, see: Cliord Matthews. The HCN World: Establishing Protein-Nucleic Acid Life via Hydrogen Cyanide Polymers. In Cellular Origin and Life in Extreme Habitats and Astrobiology (2004), 6 (Origins : Genesis, Evoluation and Diversity of Life): pp. 121-135. Retrieved August 30, 2018, from the World Wide Web
http://www.ifa.hawaii.edu/~meech/bioast/program/CDCAM.17.138.ps.

[47] Scientists Discover Two New Interstellar Molecules: Point to Probable Pathways for Chemical Evolution in Space. National Radio Astronomy Observatory. Press release, June 21, 2004. Retrieved August 30, 2018, from the World Wide Web
http://www.nrao.edu/pr/2004/GBTMolecules/
[48] Norman R. Pace. The universal nature of biochemistry. Proceedings of the National Academy of Sciences of the United States of America, Vol. 98, No. 3, Jan. 30, 2001: pp. 805-808. Retrieved August 17, 2007, from the World Wide Web
http://www.pnas.org/cgi/content/full/98/3/805
[49] Shen-Yuan Liu. Complex molecules in galactic dust cores: Biologically interesting molecules and dust chemistry. Thesis (PhD). University Of Illinois At Urbana-Champaign, Source DAI-B 60/12, p. 6152, Jun 2000. Retrieved June 11, 2002, from the World Wide Web
http://adsabs.harvard.edu/cgi-bin/nph-abs_connect.
[50] Alexandra Goho. Space Invaders The stuff of life has far-flung origins. Science News, May 1, 2004; Vol. 165, No. 18
Retrieved from the World Wide Web May 06, 2004
http://www.sciencenews.org/articles/20040501/bob9.asp
[51] David F. Blake, Peter Jenniskens. The Ice Of Life. *Scientific American*, August 2001, Vol. 285 Issue 2, p 44-50.
[52] Carbon-copy is an almost literal term. Carbon monoxide—CO—is one of the most abundant molecules produced by nova self-destruction. It appears within a mere 100 days of a nova's explosion. Formic acid (HCOOH) and methyl formate (HCOOH3), two other carbon compounds, also pop up frequently in interstellar clouds of molecules, especially in hot regions where the atom-assemblies are packed together heavily, forming what's called a "hot core." (Astronomers Find Carbon Monoxide Gas In Supernova Debris. Dartmouth News Retrieved August 30, 2018, from the World Wide Web http://www.dartmouth.edu/pages/news/releases/jan99/nova.html. Shen-Yuan Liu. Complex molecules in galactic dust cores: Biologically interesting molecules and dust chemistry. Thesis (PhD). University Of Illinois At Urbana-Champaign, Source DAI-B 60/12, p. 6152, Jun 2000. Retrieved August 30, 2018, from the World Wide Web
http://adsabs.harvard.edu/cgi-bin/nph-abs_connect.)
[53] David F. Blake, Peter Jenniskens. The Ice of Life. Scientific American, August 2001, Vol. 285, Issue 2.
Retrieved from the World Wide WebMay 27, 2003
http://web17.epnet.com/citation.asp?tb=1&_ug=dbs+7+ln+en%2Dus+sid+DD49FA4A%2D927E%2D4700%2DA8E2%2D12188543289C%40Sessionmgr4+6DA1&_us=bs+the++ice++of++life+ds+the++ice++of++life+dstb+KS+gl+SO++%22Scientific++American%22+hd+0+hs+0+or+Date+ri+KAAACBZB00075346+sm+KS+so+b+ss+SO+2921&cf=1&fn=1&rn=1
[54] Francois Raulin. Prebiotic chemistry in the solar system. In ESA, Formation of Stars and Planets, and the Evolution of the Solar System: pp. 151-157 (SEE N91-18922 10-90). Retrieved August 30, 2018, from the World Wide Web http://adsabs.harvard.edu/cgi-bin/nph-abs_connect.
[55] Max P. Bernstein, Scott A. Sandford and Louis J. Allamandola. "Life's Far-Flung Raw Materials." Scientific American, July 1999. A. G. G. Mtielens, S. B. Charnley (1997). Circumstellar and Interstellar Synthesis of Organic Molecules. Origins of Life and Evolution of the Biosphere, v. 27, Issue 1/3: pp. 23-51. Retrieved June 11, 2002, from the World Wide Web
http://adsabs.harvard.edu/cgi-bin/nph-abs_connect.
[56] David F. Blake, Peter Jenniskens. The Ice of Life. Scientific American, August 2001, Vol. 285, Issue 2.
[57] Shen-Yuan Liu. Complex molecules in galactic dust cores: Biologically interesting molecules and dust chemistry. Thesis (PhD). University Of Illinois At Urbana-Champaign, Source DAI-B 60/12, p. 6152, Jun 2000. Retrieved June 11, 2002, from the World Wide Web
http://adsabs.harvard.edu/cgi-bin/nph-abs_connect.
[58] By 2002, the number of molecules we'd found in space had climbed to 130. Rachel Nowak. Amino acid found in deep space. New Scientist, July 18, 2002
Retrieved April 25, 2005, from the World Wide Web
http://www.newscientist.com/channel/space/astrobiology/dn2558

[59] David F. Blake, Peter Jenniskens. The Ice of Life. Scientific American, August 2001, Vol. 285, Issue 2.

[60] Scientists find clues that the path leading to the origin of life begins in deep space. The Astrochemistry Laboratory in the Astrophysics Branch (SSA) of the Space Sciences Division at NASA's Ames Research Center. Retrieved August 30, 2018, from the World Wide Web http://www.astrochemistry.org/vesicle.html; Jason P. Dworkin, David W. Deamer. Scott A. Sandford, and Louis J. Allamandola. Self-assembling amphiphilic molecules: Synthesis in simulated interstellar/precometary ices. *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 98, Issue 3, January 30, 2001:pp. 815-819. Retrieved August 30, 2018, from the World Wide Web
http://www.pnas.org/cgi/content/full/98/3/815

[61] Scientists find clues that the path leading to the origin of life begins in deep space. The Astrochemistry Laboratory in the Astrophysics Branch (SSA) of the Space Sciences Division at NASA's Ames Research Center. Retrieved August 30, 2018, from the World Wide Web http://www.astrochemistry.org/vesicle.html; Jason P. Dworkin, David W. Deamer. Scott A. Sandford, and Louis J. Allamandola. Self-assembling amphiphilic molecules: Synthesis in simulated interstellar/precometary ices. *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 98, Issue 3, January 30, 2001: pp. 815-819. Retrieved August 30, 2018, from the World Wide Web
http://www.pnas.org/cgi/content/full/98/3/815

[62]. James F. Kasting. "Planetary Atmospheres: Warming Early Earth and Mars." Science, 23 May 1997: pp. 1213-1215. Heinrich D. Holland. "Evidence for Life on Earth More Than 3850 Million Years Ago." Science, 3 January 1997: pp. 38-39. Norman R. Pace "A Molecular View of Microbial Diversity and the Biosphere." Science, 2 May 1997: pp. 734-740. S.J. Mojzsis, G. Arrhenius, K.D. Mckeegan, T.M. Harrison, A.P. Nutman and C.R.L. Friend. "Evidence for life on Earth before 3,800 million years ago." Nature, 7 November 1996: pp. 55 - 59; NASA News Releases. "96-11-05 When Life Began On Earth." Retrieved December 1, 1996, from the World Wide Web http://spacelink.msfc.nasa.gov/NASA.News/NASA.News.Releases/ Previous.News.Releases/96.News.Releases/96-11.News.Releases/ 96-11-05.When.Life.Began.On.Earth, January 1999. John M. Hayes. The earliest memories of life on Earth. Nature, November 7, 1996: pp. 21-22. Minik T. Rosing. 13C-Depleted Carbon Microparticles in >3700-Ma Sea-Floor Sedimentary Rocks from West Greenland. Science, January 29, 1999: Vol. 283. no. 5402, pp. 674 - 676. DOI: 10.1126/science.283.5402.674. Minik Rosing and Robert Frei. U-rich Archaean sea-floor sediments from Greenland – indications of >3700 Ma oxygenic photosynthesis. Earth and Planetary Science Letters, Volume 217, Issues 3-4, 15 January 2004: pp. 237-244.. Paul Rincon. Oldest evidence of photosynthesis. BBC News Online, December 17, 2003.

[63] Charles H. Lineweaver, Tamara M. Davis. Does the Rapid Appearance of Life on Earth Suggest that Life Is Common in the Universe? Astrobiology. 2002, 2(3): pp. 293-304. doi:10.1089/153110702762027871.
http://www.liebertonline.com/doi/abs/10.1089/153110702762027871?cookieSet=1&journalCode=ast

[64] Qingzhu Yin, S. B. Jacobsen, K. Yamashita, J. Blichert-Toft, P. Telouk & F. Albarede. A short timescale for terrestrial planet formation from Hf–W chronometry of meteorites. Nature , Vol 418 , 29, August 2002 : pp. 949-952. Retrieved August 30, 2018, from the World Wide Web http://www.gps.caltech.edu/classes/ge133/reading/halfnium_core_nature.pdf. Claude J. Allègre, Gérard Manhès, Christa Göpel. The age of the Earth. Geochimica et Cosmochimica Acta, vol. 59, Issue 8: pp.1445-1456. Retrieved August 30, 2018, from the World Wide Web http://adsabs.harvard.edu/abs/1995GeCoA..59.1445A. Wikipedia. Planetary Formation. Retrieved August 30, 2018, from the World Wide Web
http://en.wikipedia.org/wiki/Planetary_formation.

[65] L. Bada. The transition from abiotic to biotic chemistry: When and where? American Geophysical Union, Fall Meeting 2001, abstract #U51A-11 Publication Date: 12/2001. Retrieved August 17, 2007, from the World Wide Web
http://adsabs.harvard.edu/cgi-bin/nph-abs_connect.

[66] For information on the peptiglycan weave of cellular membranes, see Franklin M. Harold. The Way of the Cell. : Molecules, Organisms and the Order of Life. NY: Oxford University Press, 2001: pp. 100-109. Jan Sapp. Cytoplasmic Heretics. Perspectives In Biology And Medicine Winter 1998: pp. 224-242.
[67] Scientists find clues that the path leading to the origin of life begins in deep space. The Astrochemistry Laboratory in the Astrophysics Branch (SSA) of the Space Sciences Division at NASA's Ames Research Center. Retrieved August 30, 2018, from the World Wide Web http://www.astrochemistry.org/vesicle.html; Jason P. Dworkin, David W. Deamer. Scott A. Sandford, and Louis J. Allamandola. Self-assembling amphiphilic molecules: Synthesis in simulated interstellar/precometary ices. *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 98, Issue 3, January 30, 2001: 815-819. Retrieved August 30, 2018, from the World Wide Web http://www.pnas.org/cgi/content/full/98/3/815. R. Cowen. Life's housing may come from space. Science News Feb 3, 2001.
Retrieved from the World Wide Web May 30, 2003
http://www.findarticles.com/cf_0/m1200/5_159/71352457/print.jhtml
[68] My extrapolation from information given by Margaret Jo Velardo, , P.A., Ph.D. McKnight Brain Institute of the University of Florida. Re: atom teams=genes. Personal communication. February 22, 2003. Also posted to International Paleopsychology Project. For an idea of the scale of the first molecules to master the art of reproduction, try these numbers. A simple SV40 virus is a collective of atoms so simple that it can NOT reproduce. It depends on genomes to do its duplication for it. Yet this extremely primitive society of atoms has 326,400 atoms. A molecule that CAN reproduce—the genome of the bacteria E. Coli—has 300,800,000 atoms, over three hundred million atoms. The first self-reproducing molecules were almost certainly atom teams whose numbers were somewhere in between these two extremes. Sources: James K. Hardy. DNA and RNA Structure and Function. In Concepts of Biochemistry. University of Akron, 1998. Retrieved August 30, 2018, from the World Wide Web http://ull.chemistry.uakron.edu/biochem/10/. R. Bennewitz, J. N. Crain, A. Kirakosian, J-L Lin, J. L. McChesney, D. Y. Petrovykh and F J Himpse. Atomic scale memory at a silicon surface. Nanotechnology 13 (2002), pp. 499-502. Institute of Physics Publishing. Retrieved August 30, 2018, from the World Wide Web http://uw.physics.wisc.edu/~himpsel/383_nano.pdf.
[69] For RNA and DNA as memory-libraries, as information-storing molecules, see: Stephen J. Freeland, Robin D. Knight, Laura F. Landweber. Molecular Evolution: Do Proteins Predate DNA? Science 22 October 1999: Vol. 286. no. 5440, pp. 690 - 692 DOI: 10.1126/science.286.5440.690 Retrieved August 19, 2007, from the World Wide Web http://www.sciencemag.org/cgi/content/full/286/5440/690. Says Ronald Breaker of Yale University's Department of Molecular, Cellular, and Developmental Biology , "DNA [is] an ideal molecule for information storage and transfer." Ronald R. Breaker. Making Catalytic DNAs. Science, December 15, 2000: Vol. 290. no. 5499: pp. 2095 – 2096. DOI: 10.1126/science.290.5499.2095. Nobel Prize-winning molecular biology pioneer Walter Gilbert, in his 1980 lecture to the Nobel Foundation declared flat out that, "DNA is **the** information store." [emphasis is mine.] Walter Gilbert. DNA sequencing and gene structure. Science, December 18, 1981: pp.1305-12. Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/reprint/214/4527/1305.pdf
[70] re: "It sometimes took storing five failed strategies to construct the mega-strategy from which a breakthrough would be made." This is a hypothesis. I've taken the liberty of extrapolating from the results of experiments like the following: B.G. Hall. Adaptive evolution that requires multiple spontaneous mutations. I. Mutations involving an insertion sequence. Genetics, December 1988: pp. 887-97; L.L. Parker, B.G. Hall. A fourth Escherichia coli gene system with the potential to evolve beta-glucoside utilization. Genetics, July 1988: pp. 485-90.
[71] Wikipedia. Cytoplasm. Retrieved August 30, 2018, from the World Wide Web http://en.wikipedia.org/wiki/Cytoplasm
[72] Genevieve Thiers. What is cytoplasm? eSSORTMENT. Pagewise 2002. Retrieved August 30, 2018, from the World Wide Web
http://wiwi.essortment.com/cytoplasm_rkkg.htm.

[73] The Gatorade inside a bacterial cell is not just rich in proteins. It's rich in protein-makers—ribosomes, small protein assembly plants. Socially, this Gatorade is a very busy place. CELLSalive! Bacterial Cell Structure. Retrieved August 30, 2018, from the World Wide Web http://www.cellsalive.com/cells/bactcell.htm

[74] Ed Rybicki, PhD Dept Microbiology. University of Cape Town. How many atoms are in a cell? Biosci/Bionet. (BIOSCI promotes communication between professionals in the biological sciences.) Retrieved June 11, 2007, from the World Wide Web. http://www.bio.net/bionet/mm/mol-evol/1997-September/005971.html

[75] James R. Lupski, George M. Weinstock, Frans J. de Bruijn. Bacterial Genomes: Physical Structure and Analysis. New York: Springer, 1998: p. 8.

[76] For RNA and DNA as memory-libraries see: Stephen J. Freeland, Robin D. Knight, Laura F. Landweber. Molecular Evolution: Do Proteins Predate DNA? Science 22 October 1999: Vol. 286. no. 5440: pp. 690 - 692 DOI: 10.1126/science.286.5440.690 Retrieved August 19, 2007, from the World Wide Web http://www.sciencemag.org/cgi/content/full/286/5440/690. Ronald R. Breaker. Making Catalytic DNAs. Science, December 15, 2000: Vol. 290. no. 5499, pp. 2095 – 2096. DOI: 10.1126/science.290.5499.2095. Walter Gilbert. DNA sequencing and gene structure. Science, December 18, 1981: 1305-12. Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/reprint/214/4527/1305.pdf

[77] E. Ben-Jacob, H. Shmueli, O. Shochet, A. Tenenbaum. "Adaptive Self-organization During Growth of Bacterial Colonies." *Physica A*, September 15, 1992: p. 378. E. Ben-Jacob, A. Tenenbaum, O. Shochet. "Holotransormations of bacterial colonies and genome cybernetics." *Physica A*. January 1994. J.A. Shapiro. "Natural genetic engineering in evolution." *Genetica*, 86:1-3 1992: 99-111. J.A. Shapiro. "Natural genetic engineering of the bacterial genome." *Current Opinion in Genetics and Development*, December 1993: pp. 845-8. J.A. Shapiro. "Genome organization, natural genetic engineering and adaptive mutation." *Trends in Genetics*, March 13, 1997: pp. 98-104.

[78] James A. Shapiro. Personal Communication. February 9-September 24, 1999.

[79] E. Ben-Jacob, A. Tenenbaum, O. Shochet, I. Cohen, A. Czirók and T. Vicsek. "Cooperative Strategies in Formation of Complex Bacterial Patterns." Fractals 3:4 (1995): pp. 849-868.

[80] Eshel Ben-Jacob. Personal Communication. January 15, 1999.

[81] James A. Shapiro. "Thinking About Bacterial Populations as Multicellular Organisms." *Annual Review of Microbiology*. Palo Alto, CA: Annual Reviews, 1998: pp. 81-104. Eshel Ben-Jacob, Israela Becker, Yoash Shapira, and Herbert Levine. Bacterial linguistic communication and social intelligence. Trends in Microbiology, 12, Issue 8, 1 August 2004: pp. 366-372.

[82] E. Ben-Jacob, A. Tenenbaum, O. Shochet, I. Cohen, A. Czirók and T. Vicsek. "Communication, Regulation and Control During Complex Patterning of Bacterial Colonies." *Fractals* Vol. 2:1 (1994): pp. 14-44.

[83] Eshel Ben-Jacob. "Bacterial wisdom, Gödel's theorem and creative genomic webs." *Physica A*, 248 (1998): pp. 57-76. Marguerite Holloway. Talking Bacteria. (Interview with Bonnie L. Bassler). Scientific American. February 2004. Retrieved August 30, 2018, from the World Wide Web http://www.sciam.com/article.cfm?chanID=sa006&colID=30&articleID=0001F2DF-27D8-1FFB-A7D883414B7F0000. Bonnie Bassler. Cell-to-Cell Communication in Bacteria. Department of Molecular Biology, Princeton University. Retrieved August 30, 2018, from the World Wide Web http://www.molbio2.princeton.edu/index.php?option=content&task=view&id=27

[84] J.W. Schopf. "Are the oldest 'fossils', fossils?" Origins of Life and Evolution of the Biosphere, January 1976: pp. 19-36. J. William Schopf and Cornelius Klein, editors. Proterozoic Biosphere: A Multidisciplinary Study. New York: Cambridge University Press, 1992. J. William Schopf. "Microfossils of the Early Archean Apex Chert: New Evidence of the Antiquity of Life." Science. 30 April 1993: pp. 640-646. J. William Schopf. Cradle of Life: The Discovery of Earth's Earliest Fossils. Berkeley: University of California Press, 1999.

[85] University of California Museum of Paleontology. Cyanobacteria: Fossil Record. Retrieved August 30, 2018, from the World Wide Web http://www.ucmp.berkeley.edu/bacteria/cyanofr.html

[86] John Tyler Bonner. The Evolution of Culture in Animals. Princeton, NJ: Princeton University Press, 1983.
[87] Matt Richardson, M.Sc.(C), and Stephen Cheung, Ph.D. The basics of thermoregulation. Agriculture Personnel Management Program. University of California, Berkeley. Retrieved August 30, 2018, from the World Wide Web http://apmp.berkeley.edu/images/stories/ManagementPractices/thermoprimer.pdf.
[88] Craig B. Stanford. The Predatory Behavior and Ecology of Wild Chimpanzees. Department of Anthropology University of Southern California Los Angeles, CA 90089-0032. Retrieved from the World Wide WebApril 04, 2004 http://www-rcf.usc.edu/~stanford/chimphunt.html. Jane Goodall. In The Shadow of Man. Boston: Houghton Mifflin, 1983 (originally published 1971).
[89] Ann Gibbons. Solving the Brain's Energy Crisis. Science, Vol 280, Issue 5368, May 29, 1998: pp. 1345-1347. Clodagh O'Brien. Early humans smart but forgetful. NewScientist.com. September 13, 2002. Retrieved September 13, 2002, from the World Wide Web http://www.newscientist.com/news/print.jsp?id=ns99992793
[90] Dian Fossey. Gorillas In the Mist. Boston: Houghton Mifflin, 1983.
[91] Our stomachs are 40% smaller than those of other animals our size. The extra energy it takes to operate a big belly is being shunted to our brain. L.C. Aiello. The Expensive Tissue Hypothesis and the Evolution of the Human Adaptive Niche: A Study in Comparative Anatomy. In Science in Archaeology: An Agenda for the Future. Edited by J. Bayley. London: English Heritage, 1998: pp. 25-36. L.C. Aiello and P. Wheeler. The Expensive Tissue Hypothesis: the brain and the digestive system in human and primate evolution. Current Anthropology, 36: (1995): pp. 199-221.
[92] Stanley H. Ambrose. Paleolithic Technology and Human Evolution. Science, Vol 291, Issue 5509, March 2, 2001: pp. 1748-1753.
[93] S. Semaw, P. Renne, J.W.K. Harris, C.S. Feibel, R.L. Bernor, N. Fesse ha, K. Mowbray. "2.5 million year old stone tools from Gona, Ethiopia." Nature, 23 January 1997: p. 333; Constance Holden. "The First Tool Kit." Science, 31 January 1997: p. 623. Ken Swisher. "Rutgers scientists discover oldest stone tools to date." Press release January 22, 1997. New Brunswick/Piscataway, NJ: Rutgers University. Downloaded April 15, 1998 from http://uc.rutgers.edu/medrel/news/envstud/gona.html. M.W. Marzke, K.L. Wullstein, S.F. Viegas. Evolution of the Power ("Squeeze") Grip and Its Morphological Correlates in Hominids. American Journal of Physical Anthropology. November, 1992; Mary W. Marzke, N. Toth, K.N. An. "EMG Study of Hand Muscle Recruitment During Hard Hammer Percussion Manufacture of Oldowan Tools." American Journal of Physical Anthropology, March 1998.
[94] A. Skinner, J. Lloyd, C. Brain and F. Thackeray. Electron spin resonance and the first use of fire. Paper presented at the 2004 Paleoanthropology Society Annual Meeting in Montreal, March 30-31, 2004. Discovering Archaeology September/October 1999. Retrieved May, 2000, from the World Wide Web http://www.discoveringarchaeology.com/0599toc/5feature3-fire.shtml. R. Rowlett, M. G. Davis, and R. B. Graber. 1999. "Friendly Fire: The First Campfires Helped Hominids Survive the Night." Discovering Archaeology 1(5): pp. 82–89. N. Alperson-Afil and N. Goren-Inbar. Out of Africa and into Eurasia with controlled use of fire: Evidence from Gesher Benot Ya'aqov, Israel. Archaeology, Ethnology and Anthropology of Eurasia.Volume 28, Number 4 / December, 2006: pp. 63-78.
[95] Richard Wrangham, Nancy Lou Conklin-Brittain. Cooking as a biological trait. Comparative Biochemistry & Physiology Part A: Molecular & Integrative Physiology; September 2003, Vol. 136 Issue 1: pp. 35-47. Richard Wrangham. Personal Communication, March 28, 2004. Natalie Angier. Cooking, and How It Slew the Beast Within. New York Times, May 28, 2002. Retrieved June 1, 2002, from the World Wide Web http://www.nytimes.com/2002/05/28/science/social/28COOK.html?pagewanted=print&position=top. For a report on Richard Wrangham's hypotheses about how cooking helped us eat inedible tubers, poisonous vegetables, see: Elizabeth Pennisi. Did Cooked Tubers Spur the Evolution of Big Brains? Science, Vol 283, Issue 5410, March 26, 1999: pp. 2004-2005.
[96] The Comm Tech Lab and the Center for Microbial Ecology at Michigan State University. The Microbe Zoo DLC ME Project, http://commtechlab.msu.edu/sites/dlc me/zoo/, downloaded September 1999. William B. Whitman, David C. Coleman, and William J. Wiebe. "Prokaryotes:

The unseen majority;" Proceedings of the National Academy of Sciences of the United States of America, Vol. 95, Issue 12, June 9, 1998: pp. 6578-6583. Richard Gallagher. "Monie a Mickle Maks a Muckle." Science, July 10, 1998: p. 186.

[97] L.C. Aiello. Hominine preadaptations for Language and Cognition. In: Modelling the Early Human Mind, edited by P. Mellars and K. Gibson. Cambrigde, UK: McDonald Institute Monographs, 1996: pp. 89-99. L.C. Aiello, Terrestriality, bipedalism and the origin of language. In: Evolution of Social Behaviour Patterns in Primates and Man, edited by J. Maynard-Smith. Proceedings of the British Academy, 88 (1996): pp. 269-289.

[98] John R. Skoyles. "Complete online text of selected papers and two books (Odyssey and Leviathan)." Retrieved August 20, 2000, from the World Wide Web http://www.users.globalnet.co.uk/~skoyles/, May, 1999.

[99] Dennis M. Bramble and Daniel E. Lieberman. Endurance running and the evolution of Homo. Nature 432, November 18, 2004: pp. 345-352. Retrieved August 21, 2007, from the World Wide Web http://www.nature.com/nature/journal/v432/n7015/full/nature03052.html

[100] P. J. Darlington, Jr. Group selection, altruism, reinforcement, and throwing in human evolution. Proceedings of the National Academy of Sciences. September 1975, Vol. 72, No. 9: pp. 3748-3752. For the changes in our physiology that made pitching and running a uniquely human killer combination, changes that arrived with *Homo erectus* 1.7 million years ago, see Alan Walker. The Search for "The Missing Link". Science & The City, Webzine of the New York Academy of Sciences. August 3, 2007. Podcast. Retrieved August 30, 2018, from the World Wide Web http://www.nyas.org/snc/podcasts.asp. William H. Calvin. The Throwing Madonna: Essays On The Brain. New York: McGraw Hill, 1983.

[101] This is the literal source of the saying, "killing two birds with one stone".

[102] Barbara Isaac. Throwing and human evolution. African Archaeological Review. Volume 5, Number 1 / December, 1987: pp. 3-17. Retrieved August 30, 2018, from the World Wide Web http://www.springerlink.com/content/q1212l4r8m7x6x5m/. For an Australian folk tale on killing an emu, a large, ostrich-like bird, with a stone toss, see: The Weeoonibeens and the Piggiebillah. The Internet Sacred Text Archive. Retrieved August 30, 2018, from the World Wide Web http://www.sacred-texts.com/aus/alt/alt09.htm

[103] Certain forms of body lice only live in human clothing. By tracing the remains of these parasites, William J. Burroughs places the date of wearing apparel at 75,000 years ago. William James Burroughs. Climate Change in Prehistory: The End of the Reign of Chaos.New York: Cambridge University Press, 2005: p. 133. The most fascinating expert on early human clothing is archaeologist Olga Soffer. For more on her views, see: Kate Wong. The Caveman's New Clothes. Profile Archaeologist Olga Soffer. Scientific American, November 2000, Vol. 283, Issue 5.

[104] Patrick Manning. Migration In World History. London: Routledge, 2005. M.F. Hammer, T. Karafet, A. Rasanayagam, et al. "Out of Africa and back again: nested cladistic analysis of human Y chromosome variation." Molecular Biology and Evolution, 15, 1998: pp. 427-441. A.R. Templeton. "Out of Africa? What do genes tell us?" Current Opinion in Genetics and Development, 7, 1997: 841 847. Kate Wong. "Is Out of Africa Going Out the Door?." Scientific American, August 1999. Retrieved July 1999, from the World Wide Web http://www.sciam.com/1999/0899issue/0899infocus.html. Clive Gamble. Timewalkers: The Prehistory of Global Colonization. Cambridge, MA: Harvard University Press, 1994.

[105.]. Olga Soffer. *The Upper Paleolithic of the Central Russian Plain*. New York: Academic Press, 1985. C.R. Harington. "Wooly Mammoth." In Animals of Beringia. December, 1995. Yukon Beringia Interpretive Centre. Retrieved November 1999, from the World Wide Web http://www.beringia.com/01student/mainb2.html#top. For a picture of a reconstructed hut made of mammoth bones and skin, see: "Mammoth bones saved Ice Age humans from winter's chill." Chicago: The Field Museum. http://www.fmnh.org/exhibits/ttt/TTT4a.htm, May 1999. For further illustrations of mammoth-bone architecture and jewelry, and for a fascinating run-through of Ukrainian pre and ancient history, see: Andrew Gregorovich. "Ancient Inventions of Ukraine." Etobicoke, Ontario, Canada: InfoUkes. Retrieved May 1999, from the World Wide Web http://www.infoukes.com/history/inventions/. For the most complete set of illustrations of mammoth-bone structures and other ice age buildings, see:

Wadyslaw Jan Kowalski. "Stone Age Habitats." Retrieved May 1999, from the World Wide Web http://www.personal.psu.edu/users/w/x/wxk116/habitat/. See also: David Lambert and the Diagram Group. The Field Guide to Early Man. New York: Facts on File Publications, 1987; and Kharlena Maria Ramanan. "Neandertal Architecture." Neandertals: A Cyber Perspective. http://thunder.indstate.edu/~ramanank/structures.html, May 1999.

[106] There is identity and vanity among animals. Bower birds build enormous architectural arches to woo mates. Other birds preen their elaborate plumage to get the attention of the girls. And some birds show off their plumage by dancing in ways that even Michael Jackson and Fred Astaire would find hard to outdo. On the identity front, whales sing songs that identify their pods and show who is part of our group and who is not. Fitting into one of these pods—and singing the right melody to prove it—can be a matter of life or death for a young whale. Janet Mann, Richard C. Connor, Peter L. Tyack, and Hal Whitehead. *Cetacean Societies: Field Studies of Dolphins and Whales.* Chicago: University of Chicago Press, 2000.

[107] Sally McBrearty, Alison S. Brooks (2000). The revolution that wasn't: a new interpretation of the origins of modern human behavior. Journal of Human Evolution 39. 5: 453-563. Lawrence S. Barham. Systematic Pigment Use in the Middle Pleistocene of South-Central Africa. Current Anthropology, Volume 43, Number 1, February 2002.

[108] Sally McBrearty, Alison S. Brooks (2000). The revolution that wasn't: a new interpretation of the origins of modern human behavior. Journal of Human Evolution 39. 5: 453-563. Ben Marwick. Pleistocene Exchange Networks as Evidence for the Evolution of Language. Cambridge Archaeological Journal; April 2003, Vol. 13 Issue 1, p. 67. Stanley H. Ambrose. Paleolithic Technology and Human Evolution. Science, Vol 291, Issue 5509 ,March 2, 2001: pp. 1748-1753. Yaroslav V Kuzmin. Michael D. Glascock, Hiroyuki Sato. Sources of Archaeological Obsidian on Sakhalin Island (Russian Far East). Journal of Archaeological Science; July 2002, Vol. 29 Issue 7: pp. 741-750. Carl Zimmer. New discoveries rewrite the book on who we are and where we came from. Discover Magazine, Vol. 24 No. 09, September 2003 J. Féblot-Augustins. Mobility strategies in the late of Central Europe and Western Europe:Elements of stability and variability. In The Middle Paleolithic Occupation of Europe, edited by W. Roebroeks, C. Gamble, Leiden: University of Leiden Press, 1999, pp. 193-214. n.a. When did we become civilised? What drove Stone Age people to abandon a hunter-gatherer lifestyle that had served them well for millennia and take on the trappings of modernity? New Scientist Magazine Issue 18 Sep 2004: pp. 32-35. K. Liu. An Annotated Survey of Bead, Glass, Faience and Archeological Publications. Ornament 25, no3, Spring 2002: pp. 22-25.

[109] Sally McBrearty, Alison S. Brooks. The revolution that wasn't: a new interpretation of the origins of modern human behavior. Journal of Human Evolution 39 2000. 5: pp. 453-563.

[110] Melville J. Herskovits. 1940. Economic Anthropology: The Economic Life of Primitive Peoples. New York: W.W. Norton, 1965.

[111] Christopher Henshilwood, Francesco d'Errico, Marian Vanhaeren, Karen van Niekerk, Zenobia Jacobs. Middle Stone Age Shell Beads from South Africa. Science, Vol 304, Issue 5669, April 16, 2004: p. 16. Bryn Nelson. Constance Holden. Oldest Beads Suggest Early Symbolic Behavior. Science, April 16, 2004: p. 404. Bryn Nelson. Is this the oldest known piece of jewelry? Newsday.com, April 15, 2004.
Retrieved from the World Wide Web April 17, 2004.
http://www.newsday.com/news/health/ny-hsbead0416,0,665750,print.story?coll=ny-health-big-pix
NY Newsday.com

[112] Ian Tattersall. Becoming Human: Evolution and Human Uniqueness. New York: Harcourt, 1998. Retrieved August 30, 2018, from the World Wide Web
http://www.human-nature.com/darwin/books/tattersall.html

[113] Heather Pringle. "The Slow Birth of Agriculture." Science, 20 Nov 1998:: p. 1446. D.B. Grigg. The Agricultural Systems of the World: An Evolutionary Approach. Cambridge: Cambridge University Press, 1974. Manfred Heun, Ralf Schafer-Pregl, Dieter Klawan, Renato Castagna, Monica Accerbi, Basilio Borghi, Francesco Salamini. "Site of Einkorn Wheat Domestication Identified by DNA Fingerprinting." Science, November 14, 1997: pp. 1312-1322. C. Mlot. "Wheat's DNA points to first farms." Science News, November 15, 1997: p. 308.

[114] Howard Bloom. Global Brain: The Evolution of Mass Mind From The Big Bang to the 21st Century. New York: John Wiley and Sons, 2000. Kathleen M. Kenyon. "Excavations at Jericho, 1957-58." Palestine Excavation Quarterly, 92, 1960: pp. 88-108; Purushottam Singh. Neolithic Cultures of Western Asia. New York: Seminar Press, 1974: pp. 33-47. James Mellaart. Catal-Huyuk: A Neolithic Town in Anatolia. New York: McGraw-Hill, 1967. Michael Balter. "Why Settle Down? The Mystery of Communities." Science, 20 November 1998: pp. 1442-1445. Dora Jane Hamblin with C.C. Lamberg-Karlovsky and the editors of Time-Life Books. The Emergence of Man: The First Cities. New York: Time-Life Books, 1979: pp. 29-32, 910. David Ussishkin. "Notes on the Fortifications of the Middle Bronze II Period at Jericho and Shechem." Bulletin of the American Schools of Oriental Research, November, 1989.

[115] Howard Bloom. Global Brain: The Evolution of Mass Mind From The Big Bang to the 21st Century. New York: John Wiley and Sons, 2000.

[116] Howard Bloom. The Lucifer Principle: a scientific expedition into the forces of history. New York: Atlantic Monthly Press, 1995.

[117] History of Life on Earth. Department of Biological Sciences, Northern Illinois University. Retrieved August 30, 2018, from the World Wide Web www.bios.niu.edu/johns/bios103/history_of_life.ppt

[118] Lynn Margulis and Dorion Sagan. Microcosmos: Four Billion Years of Microbial Evolution. New York: Summit Books, 1986.

[119] Lynn Margulis. Symbiosis in Cell Evolution: Microbial Communities in the Archean and Proterozoic Eons, Second Edition. New York: W.H. Freeman, 1993. Lynn Margulis. Personal Communication. March 22, 1997.

[120] n.a. Conceptual depiction of complex interactions in coastal seafloor sediments. Water & Atmosphere online. NIWA Science. National Institute of Water and Atmospheric Research, Auckland, New Zealand. Retrieved August 30, 2018, from the World Wide Web http://www.niwa.cri.nz/pubs/wa/12-3/images/sediment2_large.jpg/view. N.a. Sedimentology. Organic Influences on Sediments. Derby, UK: University of Derby. Retrieved August 30, 2018, from the World Wide Web http://www.virtual-geology.info/sedimentology/organic.html. Wikipedia. Sedimentology. Retrieved August 30, 2018, from the World Wide Web http://en.wikipedia.org/wiki/Sedimentology

[121] Mark Shrope and John Pickrell. Mysteries of the Deep Sea. NewScientist Environment. September 4, 2006. Retrieved August 30, 2018, from the World Wide Web http://environment.newscientist.com/channel/Earth/deep-sea/dn9967

[122] John Gage. Deep-sea spiral fantasies. Nature 434, March 17, 2005: pp. 283-284 | doi:10.1038/434283a; Published online 16 March 2005. Retrieved August 30, 2018, from the World Wide Web http://www.nature.com/nature/journal/v434/n7031/full/434283a.html. n.a. Cold Seep Communities. Astrobiology Magazine, November 16, 2006. Retrieved August 30, 2018, from the World Wide Web http://astrobio.net/news/article2146.html

[123] Sid Perkins. Attack of the Rock-Eating Microbes! Science News, Nov. 15, 2003; Vol. 164, No. 20: p. 315. Retrieved August 23, 2007, from the World Wide Web http://www.sciencenews.org/articles/20031115/bob9.asp
W. Bach and K.J. Edwards. Iron and sulfide oxidation within the basaltic ocean crust: Implications for chemolithoautotrophic microbial biomass production. Geochimica et Cosmochimica Acta 67, Oct. 15, 2003: pp.3871-3887. Thomas M. Bawden, Marco T. Einaudi, Benjamin C. Bostick, Anders Meibom, Joseph Wooden, John W. Norby, Michael J.T. Orobona, and C. Page Chamberlain. Extreme 34S depletions in ZnS at the Mike gold deposit, Carlin Trend, Nevada: Evidence for bacteriogenic supergene sphalerite. Geology 31, October 2003: pp.913-916. Katrina J. Edwards, Thomas M. McCollom, Hiromi Konishi and Peter R. Buseck. Seafloor bioalteration of sulfide minerals: Results from in situ incubation studies. Geochimica et Cosmochimica Acta 67, Aug. 1, 2003:pp. 2843-2856. Katrina J. Edwards, W. Bach, and D.R. Rogers. Geomicrobiology of the ocean crust: A role for chemoautotrophic Fe-bacteria. Biological Bulletin 204,April 2003: pp.180-185. Katrina J. Edwards, D. R. Rogers, C. O. Wirsen, and T. M.

McCollom. Isolation and characterization of novel psychrophilic, neutrophilic, Fe-oxidizing, chemolithoautotrophic alpha-and gamma-proteobacteria from the Deep Sea. Applied and Environmental Microbiology 69, May 2003: pp. 2906-2913. R.S. Oremland and J.F. Stolz. The ecology of arsenic. Science 300, May 9, 2003: pp.939-944. A. Todd, D. McKnight, and L. Wyatt. Abandoned mines, mountain sports, and climate variability: Implications for the Colorado tourism economy. EOS 84(Sept. 23, 2003): p. 377. Matthias Labrenz, Gregory K. Druschel, Tamara Thomsen-Ebert, Benjamin Gilbert, Susan A. Welch, Kenneth M. Kemner, Graham A. Logan, Roger E. Summons, Gelsomina De Stasio, Philip L. Bond, Barry Lai, Shelly D. Kelly, Jillian F. Banfield. Formation of sphalerite (ZnS) deposits in natural biofilms of sulfate-reducing bacteria. Science 290, Dec. 1, 2000: pp. 1744-1747.

[124] Sid Perkins. Signs of Life? Organisms' effects on terrain aren't all that easy to perceive. Science News Aug. 4, 2007; Vol. 172, No. 5 Retrieved August 30, 2018, from the World Wide Web http://www.sciencenews.org/articles/20070804/bob10.asp

[125] Sid Perkins. Signs of Life? Organisms' effects on terrain aren't all that easy to perceive. Science News Aug. 4, 2007; Vol. 172, No. 5 Retrieved August 30, 2018, from the World Wide Web http://www.sciencenews.org/articles/20070804/bob10.asp

[126] Charles Darwin. The formation of vegetable mould through the action of worms: With observations of their habits. London: J. Murray, 1904.

[127] Lyle B. Steadman , Craig T. Palmer , Christopher F. Tilley. The universality of ancestor worship. Ethnology, Vol. 35, 1996. Retrieved August 30, 2018, from the World Wide Web http://www.questia.com/googleScholar.qst;jsessionid=GTMVQT7QKn2b1LKtcnFgsHW5Z2DzvrGr5JK3Vny9TLMyDxTLgL1W!1926754150?docId=5000324827. Personal communications with Lyle Steadman, 1997.

[128] These thousand of pages include the four books of the Hadith—the eyewitness accounts of Mohammed's life and the early biographies of Mohammed, one of which, al Tabari's History, is 39 books long. See: Sahih Bukhari. Translator: M. Muhsin Khan. MSA-USC Hadith Database. USC-MSA Compendium of Muslim Texts. University of Southern California.
Retrieved August 22, 2005, from the World Wide Web
http://www.usc.edu/dept/MSA/fundamentals/hadithsunnah/bukhari/
Sahih Muslim. The Book of Faith (Kitab Al-Iman)' of Sahih Muslim. Translated by Abdul Hamid Siddiqui. In SearchTruth.com.
Retrieved February 19, 2006, from the World Wide Web
http://www.searchtruth.com/hadith_books.php. Ibn Ishaq. Sirat Rasoul Allah: The earliest biography of Muhammad, by ibn Ishaq. An abridged version Edited by Michael Edwardes. Retrieved June 5, 2006, from the World Wide Web
http://www.faithfreedom.org/Articles/sira/index.htm . al-Tabari. A. Guillaume. The Life of Muhammad: A Translation of Ibn Ishaq's Sirat Rasul Allah. New York: Oxford University Press, 1955 , eighteenth printing, 2004. The History of al Tabari: Complete volume set from 1 to 39 : English translation of "at Tareekh al Tabari" various translators. Albany: State University of New York Press. Al Tabari's history alone in English translation comes to 4700 pages.

[129] Wikipedia. Buddhist Texts. Retrieved August 30, 2018, from the World Wide Web http://en.wikipedia.org/wiki/Buddhist_texts#Canonical_texts.

[130] Howard Bloom. Global Brain: The Evolution of Mass Mind From The Big Bang to the 21st Century. New York: John Wiley and Sons, 2000.

[131] Sid Perkins. Signs of Life? Organisms' effects on terrain aren't all that easy to perceive. Science News Aug. 4, 2007; Vol. 172, No. 5 Retrieved August 30, 2018, from the World Wide Web http://www.sciencenews.org/articles/20070804/bob10.asp

[132] Tom Young. What is the volume of Earth?
Physlink.com—Physics & Astronomy Online. Retrieved August 30, 2018, from the World Wide Web http://www.physlink.com/Education/AskExperts/ae419.cfm

[133] Ellen Trimarco, David Balkwill, Mark Davidson, T. C. Onstott. In Situ Enrichment of a Diverse Community of Bacteria from a 4-5 km Deep Fault Zone in South Africa. Geomicrobiology Journal, Volume 23, Issue 6, September 2006: pp. 463 - 473. http://www.informaworld.com/smpp/content~content=a759195485~db=all. Tullis Onstott.

Research Statement. Geosciences@Princeton. Updated 09/25/06. Retrieved August 30, 2018, from the World Wide Web http://geoweb.princeton.edu/people/onstott/research.html. Richard Monastersky. Deep Dwellers Microbes thrives far below ground. Science News, March 29, 1997. Retrieved May 2, 2005, from the World Wide Web http://www.sciencenews.org/pages/sn_arc97/3_29_97/bob1.htm. Thomas Gold. The Deep Hot Biosphere. New York, Springer, 1999.

[134] According to David Raup and J. John Sepkoski's canonical paper on the statistical parameters of "major extinctions", during the last 250 million years, there have been twelve mass extinctions, "with a mean interval between events of 26 million years". If we extend this average, one mass extinction every 26 million years, back through the 3.85 billion years of life on this planet, we arrive at an estimate of 148 mass extinctions since life begain. David M. Raup and J. John Sepkoski. Periodicity of Extinctions in the Geologic Past. Proceedings of the National Academy of Sciences, February 1, 1984, vol. 81, no. 3: pp. 801-805.

[135] David M. Raup and J. John Sepkoski. Periodicity of Extinctions in the Geologic Past. Proceedings of the National Academy of Sciences, February 1, 1984, vol. 81, no. 3: pp. 801-805.

[136] Donald R. Lowe and Michael M. Tice. Geologic evidence for Archean atmospheric and climatic evolution: Fluctuating levels of CO2, CH4, and O2 with an overriding tectonic control. Geology, June 2004, v. 32; no. 6: p. 493-496; DOI: 10.1130/G20342.1. Retrieved August 30, 2018, from the World Wide Web http://geology.geoscienceworld.org/cgi/content/abstract/32/6/493

[137] J.F. Kasting. Theoretical constraints on oxygen and carbon dioxide concentrations in the Precambrian atmosphere. Precambrian Research 1987; 34: pp. 205-29. Retrieved August 24, 2007, from the World Wide Web http://www.ncbi.nlm.nih.gov/sites/entrez?cmd=Retrieve&db=PubMed&list_uids=11542097&dopt=Citation. Kasting is with NASA Ames Research Center. But Nathan D. Sheldon of the Royal Holloway University of London believes Kasting's figures for CO2 levels are not high enough. Nathan D. Sheldon. Precambrian paleosols and atmospheric CO2 levels. Precambrian Research, Volume 147, Issues 1-2, 10 June 2006, pp: 148-155. Virginia Tech. Atmospheric Carbon Dioxide Greater 1.4 Billion Years Ago. ScienceDaily, September 19, 2003. Retrieved from the World Wide WebSeptember 21, 2003 http://www.sciencedaily.com/releases/2003/09/030918092804.htm

[138] Paul Recer. Radio astronomers measure sun's orbit around Milky Way. Associated Press, June 1, 1999. For a list of the varied estimates of the sun's orbit around the core of our galaxy, estimates that are all in the 226 million year ballpark, see: Glenn Elert, editor. Period of the Sun's Orbit around the Galaxy (Cosmic Year). In The Physics Factbook. Retrieved August 30, 2018, from the World Wide Web http://hypertextbook.com/facts/2002/StacyLeong.shtml.

[139] For the high correlation between mass extinctions and our 226 million year trip around the galactic core, see: G. N. Goncharov and V. V. Orlov. Global repeating events in the history of the Earth and the motion of the Sun in the Galaxy. Astronomy Reports, Volume 47, Number 11 / November, 2003: pp. 925-933.

[140] Stephen J. Kortenkamp, Stanley F. Dermott. A 100,000-Year Periodicity in the Accretion Rate of Interplanetary Dust. Science, May 8, 1998: Vol. 280. no. 5365: pp. 874 – 876. DOI: 10.1126/science.280.5365.874 Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/content/full/280/5365/874
Kristen Vecellio. Interplanetary Dust May Cause Climate Change, Gradual Extinction. Stardust/JPL/NASA. NASA Jet Propulsion Laboratory, California Institute of Technology, May 7, 1998. Retrieved August 30, 2018, from the World Wide Web http://stardust.jpl.nasa.gov/news/news19.html. There's a surge of interstellar dust piling up in our solar system at this very moment, the kind that can produce massive climate shifts. See: Ron Cowen. It's Raining Stardust: Spacecraft measures record amount of stellar debris. Science News, August 23, 2003; Vol. 164, No. 8.
Retrieved from the World Wide Web September 05, 2003
http://www.sciencenews.org/20030823/fob2.asp
Science News Week of Aug. 23, 2003; Vol. 164, No. 8

[141] Nir Shaviv. New research suggests that ice age epochs on the Earth may result from our solar system's trek through the spiral arms of the Milky Way. Physics News 599, July 24, 2002.
[142] R. Bruce McMillan, Rickard S. Toomey, III, Erich Schroeder, Russell W. Graham, Eric C. Grimm, Pietra G. Mueller, Jeffrey J. Saunders, and Bonnie W. Styles. Ice Ages: When have Ice Ages occurred? Springfield, IL. Illinois State Museum. second edition, 2002. Retrieved August 30, 2018, from the World Wide Web
http://www.museum.state.il.us/exhibits/ice_ages/when_ice_ages.html
[143] Steven Mithen. The Prehistory of the Mind: the cognitive origins of art, religion and science. London: Thames and Hudson, 1996. "Homo habilis." Encyclopædia Britannica. 2007. Encyclopædia Britannica Online. Retrieved August 30, 2018, from the World Wide Web
25 Aug. 2007 <http://www.britannica.com/eb/article-9040897>. See also: Homo erectus. (2007). In Encyclopædia Britannica. Retrieved August 25, 2007, from Encyclopædia Britannica Online: http://www.britannica.com/eb/article-249981. "Australopithecus." Encyclopædia Britannica. 2007. Encyclopædia Britannica Online. Retrieved August 30, 2018, from the World Wide Webhttp://www.britannica.com/eb/article-9011337.
[144] Steven Mithen. The Prehistory of the Mind: the cognitive origins of art, religion and science. London: Thames and Hudson, 1996: pp. 24-26.
[145] Technically these instant global warmings are called Dansgaard–Oeschger events. In the 120,000 years since the end of the Eemian interglacial, these instant global warmings have occurred roughly every 1,500 years. Stefan Rahmstorf . Ocean circulation and climate during the past 120,000 years. Nature 419, September 12, 2002: pp. 207-214 | doi:10.1038/nature01090 Retrieved August 25, 2007, from the World Wide Web
http://www.nature.com/nature/journal/v419/n6903/abs/nature01090.html.
[146] Fenella Saunders. Chaotic Warnings From the Last Ice. Discover, Vol. 23 No. 6, June 2002. Retrieved August 25, 2007, from the World Wide Web
http://discovermagazine.com/2002/jun/breakice.
[147] D.O. Gough. Solar interior structure and luminosity variations. Solar Physics, Volume 74, Number 1, November, 1981: pp. 21-34. Retrieved August 30, 2018, from the World Wide Web http://www.springerlink.com/content/w316383474k03835/ . How To Mend A Broken Climate, interview with Climatologist Ken Caldeira. Discover, April 2003, Vol. 24, Issue 4. Gabrielle Walker. The Longest Winter. Natural History, April 2003, Vol. 112, Issue 3.
[148] Richard A. Kerr. Early Life Thrived Despite Earthly Travails. Science June 25, 1999; 284: 2111 2113.
[149] Richard A. Muller and Gordon MacDonald. Ice Ages and Astronomical Causes. New York: Springer-Praxis, 2000. Retrieved August 30, 2018, from the World Wide Web
http://muller.lbl.gov/pages/IceAgeBook/history_of_climate.html
[150] Kathleen M. Kenyon. "Excavations at Jericho, 1957-58." Palestine Excavation Quarterly, 92, 1960: 88-108.M. Gimbutas. "Wall Paintings of Catal Huyuk." The Review of archaeology. Fall 1990. James Mellaart. Catal-Huyuk: A Neolithic Town in Anatolia. New York: McGraw-Hill, 1967. Hans Helback. "First impressions of the Catal Huyuk plant husbandry." Anatolian Studies, XIV, 1964: 121-123. Borghi, Francesco Salamini. "Site of Einkorn Wheat Domestication Identified by DNA Fingerprinting." Science, 14 November 1997: pp. 1312-1322. Howard Bloom. Global Brain: The Evolution of Mass Mind From The Big Bang to the 21st Century. New York: John Wiley and Sons, 2000.
[151] . Stefan Rahmstorf . Ocean circulation and climate during the past 120,000 years. Nature 419, September 12, 2002: pp. 207-214 | doi:10.1038/nature01090
Retrieved August 25, 2007, from the World Wide Web
http://www.nature.com/nature/journal/v419/n6903/abs/nature01090.html. Andrew J. Weaver, Oleg A. Saenko, Peter U. Clark, Jerry X. Mitrovica. Meltwater Pulse 1A from Antarctica as a Trigger of the Bølling-Allerød Warm Interval. Science March 14, 2003: Vol. 299. no. 5613: pp. 1709 - 1713 | DOI: 10.1126/science.1081002. Retrieved August 30, 2018, from the World Wide Web
http://www.sciencemag.org/cgi/content/short/299/5613/1709
[152] J. D. Hays, John Imbrie, and N. J. Shackleton. Variations of the Earth's orbit: Pacemaker of the ice ages. Science, December 10, 1976: Vol. 194. no. 4270: pp. 1121 - 1132 | DOI:

10.1126/science.194.4270.1121. http://www.sciencemag.org/cgi/reprint/194/4270/1121.pdf. Stefan Rahmstorf. Timing of abrupt climate change: a precise clock. Geophysical Research Letters, vol. 30, no. 10, March 2003. Retrieved August 30, 2018, from the World Wide Web http://pik-potsdam.de/~stefan/Publications/Journals/rahmstorf_grl_2003.pdf. Stefan Rahmstorf . Ocean circulation and climate during the past 120,000 years. Nature 419, September 12, 2002: pp. 207-214 | doi:10.1038/nature01090
Retrieved August 25, 2007, from the World Wide Web http://www.nature.com/nature/journal/v419/n6903/abs/nature01090.html. For a history and explanation of the Milankovich Effect see: "climate" Encyclopædia Britannica Online. Retrieved November 23, 2000, from the World Wide Web
http://members.eb.com/bol/topic?eu=109112&sctn=19. For a dissenting voice on the impact of the Milankovich Effect, see: Richard A. Muller and Gordon MacDonald. Ice Ages and Astronomical Causes. New York: Springer-Praxis, 2000. Retrieved August 30, 2018, from the World Wide Web
http://muller.lbl.gov/pages/IceAgeBook/history_of_climate.html

[153] "Our modern climate represents a very short, warm period between glacial advances." R. Bruce McMillan, Rickard S. Toomey, III, Erich Schroeder, Russell W. Graham, Eric C. Grimm, Pietra G. Mueller, Jeffrey J. Saunders, and Bonnie W. Styles. Ice Ages: When have Ice Ages occurred? Springfield, IL. Illinois State Museum. second edition, 2002. Retrieved August 30, 2018, from the World Wide Web http://www.museum.state.il.us/exhibits/ice_ages/when_ice_ages.html. "It is clear that most of the last 420 thousand years (420 kyr) was spent in ice age…. The very unusual nature of the last 11,000 years stands out in striking contrast to the 90,000 years of cold that preceded it." Richard A. Muller and Gordon MacDonald. Ice Ages and Astronomical Causes. New York: Springer-Praxis, 2000. Retrieved August 30, 2018, from the World Wide Web http://muller.lbl.gov/pages/IceAgeBook/history_of_climate.html. "Abrupt climate events appear to be paced by a 1,470-year cycle with a period that is probably stable to within a few percent.... This highly precise clock points to an origin outside the Earth system...." Stefan Rahmstorf. Timing of abrupt climate change: a precise clock. Geophysical Research Letters, vol. 30, no. 10, March 2003. Retrieved August 25, 2007, from the World Wide Web http://pik-potsdam.de/~stefan/Publications/Journals/rahmstorf_grl_2003.pdf. Thomas J. Crowley and Gerald R. North. Abrupt Climate Change and Extinction Events in Earth History. Science, May 20, 1988: Vol. 240. no. 4855: pp. 996 - 1002 DOI: 10.1126/science.240.4855.996.

[154] Even the most optimistic experts on climatological history compare our temporary truce with the ice to another highly unusual period that lasted 28,000 years. The wildly out-of-character thaw whose example these scientists hope our epoch will follow is "the interglacial stage following Termination V". EPICA community members. Eight glacial cycles from an Antarctic ice core. Nature 429, June 10, 2004: pp. 623-628 | doi:10.1038/nature02599; Retrieved August 30, 2018, from the World Wide Web
http://www.nature.com/nature/journal/v429/n6992/abs/nature02599.html

[155] Howard Bloom. The Lucifer Principle: a scientific expedition into the forces of history. New York: Grove/Atlantic, 1997.

[156] UNESCO MAB—Man and Biosphere Programme. People, Diversity and Ecology. Retrieved August 30, 2018, from the World Wide Web
http://www.unesco.org/mab/ecosyst/islands.shtml. The Socioeconomic data and Applications Center puts the percentage of humans living in coastal areas at 40%. SEDAC—Socioeconomic data and Applications Center. Percentage of Total Population Living in Coastal Areas. July 2007. Retrieved August 30, 2018, from the World Wide Web
http://sedac.ciesin.org/es/papers/Coastal_Zone_Pop_Method.pdf

[157] John Boardman, Jasper Griffin, Oswyn Murray. The Oxford History of the Classical World: Greece and the Hellenistic World. New York: Oxford University Press, 1988.

[158] These insights on the evolution of the Family of DNA were stimulated by the work of David Smillie: David Smillie. "Human Nature and Evolution: language, culture, and race." Paper given at the Biennial Meeting of the International Society of Human Ethology, Amsterdam, August 1992. David Smillie. "Darwin's Tangled Bank: The Role of Social Environments." Perspectives in

Ethology, Volume 10: Behavior and Evolution, edited by P.P.G. Bateson, et. al., pp. 119-141. New York: Plenum Press, 1993. David Smillie. "Darwin's Two Paradigms: An 'Opportunistic' Approach to Group Selection Theory." Journal of Social and Evolutionary Systems 18(3) (1995): pp. 231-255. David Smillie. "Group processes and human evolution: sex and culture as adaptive strategies." Paper presented at the 19th Annual Meeting of the European Sociobiological Society, Alfred, NY, July 25, 1996.

159 For example, autotrophs kidnap carbon dioxide, chemolithoautotrophs use hydrogen, iron, sulfur, ammonia, and nitrites, chemoorganoheterotrophs use miscellaneous chemical compounds, and uncategorized bacteria use methane and carbon monoxide. NASA. Life on Other Planets in the Solar System.—Looking for Extraterrestrial life. Viability of Micro-organisms. TABLE 1.2 Microorganisms with Particular Physiological and Nutritional Characteristics. Retrieved August 30, 2018, from the World Wide Web http://www.resa.net/nasa/extreme_chart.htm. For another example, see the ways in which bacteria make use of inanimate sulfur atoms: Agnieszka Sekowska & Antoine Danchin. Sulfur metabolism in Bacteria, with emphasis on Escherichia coli and Bacillus subtilis. Genetics of Bacterial Genomes. Pasteur Institute, France. Retrieved August 30, 2018, from the World Wide Web http://www.pasteur.fr/recherche/unites/REG/sulfur_review.html.

160 Lynn Margulis. Symbiosis in Cell Evolution: Microbial Communities in the Archean and Proterozoic Eons, Second Edition. New York: W.H. Freeman, 1993. Lynn Margulis and Dorion Sagan. Microcosmos: Four Billion Years of Microbial Evolution. New York: Summit Books, 1986.

161 R K Thauer, K Jungermann, and K Decker. Energy conservation in chemotrophic anaerobic bacteria. Microbiology and Molecular Biology Reviews, Vol. 41, Issue 1, March 1, 1977: pp: 100-180. Microbiology. Edward F. DeLong. Life on the thermodynamic edge. Science. 2007 July 20; 317(5836): pp. 327-8.

162 Effect of Hydrogenase and Mixed Sulfate-Reducing Bacterial Populations on the Corrosion of Steel. Richard D. Bryant, Wayne Jansen, Joe Boivin, Edward J. Laishley, and J. William Costerton. Applied and Environmental Microbiology, October 1991: pp. 2804-2809.

163 R.L. Anderson, B.W. Holland, J.K. Carr, W.W. Bond, M.S. Favero. Effect of disinfectants on pseudomonads colonized on the interior surface of PVC pipes. American Journal of Public Health, 80 (1), January 1990: pp. 17-21. These pipe-eating microbes managed to survive heavy-duty assaults with disinfectants, including chlorine, phenolic, ethanol, quaternary-ammonium, and idiophor.

164 Andy Coghlan, Mapping the Slime Cities. World Press Review, December 1996: pp. 32-33.

165 J.M. Gonzales, J.E. Brown, F.T. Robb, et al. Microbial diversity, metabolism, and interaction. Meeting of the American Society for Microbiology. May 1998, Atlanta. J. Travis. Novel bacteria have a taste for aluminum. Science News, Vol. 153, No. 22, May 30, 1998: p. 341. For a dissenting opinion, one that states that aluminum is toxic to **all** bacteria, see Rogelio Garcidueñas Piña and Carlos Cervantes. Microbial interactions with aluminum. BioMetals Volume 9, Number 3 / July, 1996: p. 311-316.

166 V. Epshtein, A.S. Mironov, and E. Nudler. The riboswitch-mediated control of sulfur metabolism in bacteria. Proceedings of the National Academy of Sciences, April 29, 2003: pp. 5052-5056. Retrieved August 30, 2018, from the World Wide Web http://www.pnas.org/cgi/content/full/100/9/5052

167 The champion of bacteria that have invented ways to thrive in a radioactive environment is Deinococcus radiodurans. For more on Deinococcus radiodurans survival tricks, see: Y.Hua, I. Narumi, G. Gao, B. Tian, K. Satoh, S. Kitayama, B. Shen. PprI: a general switch responsible for extreme radioresistance of Deinococcus radiodurans. Biochemical and Biophysical Research Communications. June 2003 27; 306 (2): pp. 354-60. Retrieved August 30, 2018, from the World Wide Web http://www.ncbi.nlm.nih.gov/sites/entrez?Db=PubMed&Cmd=ShowDetailView&TermToSearch=12804570&ordinalpos=1&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_RVAbstractPlus . JR. Battista. Against all odds: the survival strategies of Deinococcus radiodurans. Annual Review of Microbiology. 1997; 51: pp. 203-24. Retrieved August 30, 2018, from the World Wide Web http://www.ncbi.nlm.nih.gov/sites/entrez?cmd=Retrieve&db=PubMed&list_uids=9343349

John Travis. Two-handed protein may protect DNA. Science News, July 3, 2004; Vol. 166, No. 1. Retrieved July 22, 2004, from the World Wide Web http://www.sciencenews.org/articles/20040703/note13.asp. Patrick Huyghe. Conan the Bacterium. The Sciences, July/August 1998: pp. 16-19.

[168] Gerald W. Tannock. Normal Microflora: An Introduction to Microbes Inhabiting the Human Body. New York: Springer, 1995.

[169]. Stuart B. Levy. The Antibiotic Paradox: How Miracle Drugs are Destroying the Miracle. New York: Plenum Press, 1992. Stuart B. Levy, M.D. "Multidrug Resistance—A Sign of the Times." The New England Journal of Medicine, May 7, 1998. The Center for Adaptation Genetics and Drug Resistance, Retrieved January 1999, from the World Wide Web http://www.healthsci.tufts.edu/labs/Sblevy/home.html. Stuart B. Levy. The Challenge of Antibiotic Resistance. Scientific American, March 1998: pp. 46-53. For animal evidence supporting Levy's contention that we are defended by our internal bacterial occupiers, see: S.P. Borriello, F.E. Barclay. Protection of hamsters against Clostridium difficile ileocaecitis by prior colonisation with non-pathogenic strains. Journal of Medical Microbiology, June 1985: pp. 339-50. F. Le Guyader, M. Pommepuy, M. Cormier. Implantation of Escherichia coli in pilot experiments and the influence of competition on the flora. Canadian Journal of Microbiology, February 1991: pp. 116-121; D.J. Bibel, R. Aly, C. Bayles, W.G. Strauss, H.R. Shinefield, H.I. Maibach. Competitive adherence as a mechanism of bacterial interference. Canadian Journal of Microbiology, June 1983: pp. 700-703. A. Onderdonk, B. Marshall, R. Cisneros, S.B. Levy. Competition between congenic Escherichia coli K-12 strains in vivo. Infection and Immunity, April 1981: pp. 74-9. N. Rikitomi, M. Akiyama, K. Matsumoto. Role of normal microflora in the throat in inhibition of adherence of pathogenic bacteria to host cells: in vitro competitive adherence between Corynebacterium pseudodiphtheriticum and Branhamella catarrhalis. Kansenshogaku Zasshi, February 1989: pp.118-24; C.S. Impey, G.C. Mead, S.M. George. Competitive exclusion of salmonellas from the chick caecum using a defined mixture of bacterial isolates from the caecal microflora of an adult bird. Journal of Hygiene, December 1982: pp. 479-90. M. Hinton, G.C. Mead, C.S. Impey. Protection of chicks against environmental challenge with Salmonella enteritidis by `competitive exclusion' and acid-treated feed. Letters in applied microbiology. March 1991. F.W. Edens, C.R. Parkhurst, I.A. Casas, W.J. Dobrogosz. Principles of ex ovo competitive exclusion and in ovo administration of Lactobacillus reuteri. Poultry Science, January 1997: pp. 179-196. M.E. Hume, J.A. Byrd, L.H. Stanker, H.L. Ziprin. Reduction of caecal Listeria monocytogenes in Leghorn chicks following treatment with a competitive exclusion culture (PREEMPT)."] Letters in Applied Microbiology, June 1998: pp. 432-6. M. Aho, L. Nuotio, E. Nurmi, T. Kiiskinen. Competitive exclusion of campylobacters from poultry with K-bacteria and Broilact. International Journal of Food Microbiology, March-April 1992: pp. 265-75. Katrin Pütsep, Carl-Ivar Brändén, Hans G. Boman, Staffan Normark. Antibacterial peptide from H. pylori. *Nature*, 22 April 1999: pp. 671-672.

[170] D.M. Fallacara, C.M. Monahan, T.Y. Morishita, and R.F. Wack. Fecal Shedding and Antimicrobial Susceptibility of Selected Bacterial Pathogens and a Survey of Intestinal Parasites in Free-Living Waterfowl. Avian Diseases, Vol. 45, No. 1 January - March, 2001: pp. 128-135 | doi:10.2307/1593019

[171] Bugs may control weather. CNN. Retrieved March 15, 2003, from the World Wide Web http://www.cnn.com/2002/WEATHER/05/27/bugs.weather/index.html. Oliver Morton. The Living Skies: Cloud Behavior and its Role in Climate Change. The Hybrid Vigor Journal, April 2002. Retrieved August 30, 2018, from the World Wide Web http://www.hybridvigor.net/Earth/pubs/HVclouds.pdf

[172] "There are over 10000 species of birds in the world." Birding.com. Retrieved August 30, 2018, from the World Wide Web http://www.birding.com/species.asp. The total of mammal species comes to a mere 4,629. (World Resource Institute. Species: Mammal species, number. Retrieved August 30, 2018, from the World Wide Web http://Earthtrends.wri.org/searchable_db/index.php?action=select_countries&theme=7&variable_ID=119)