The Xerox Effect

on the importance of pre-biotic evolution

by

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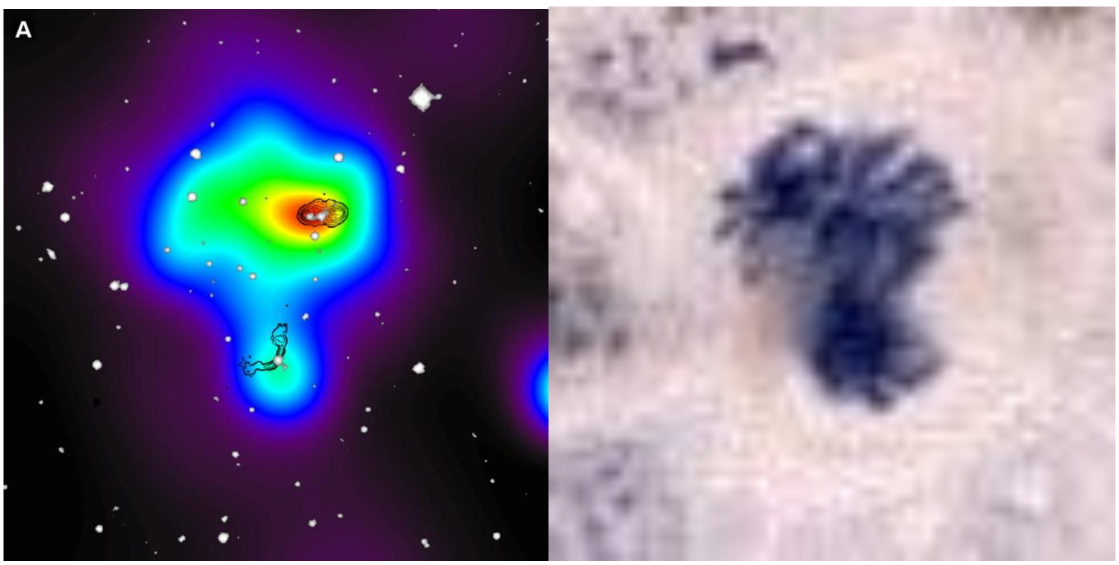
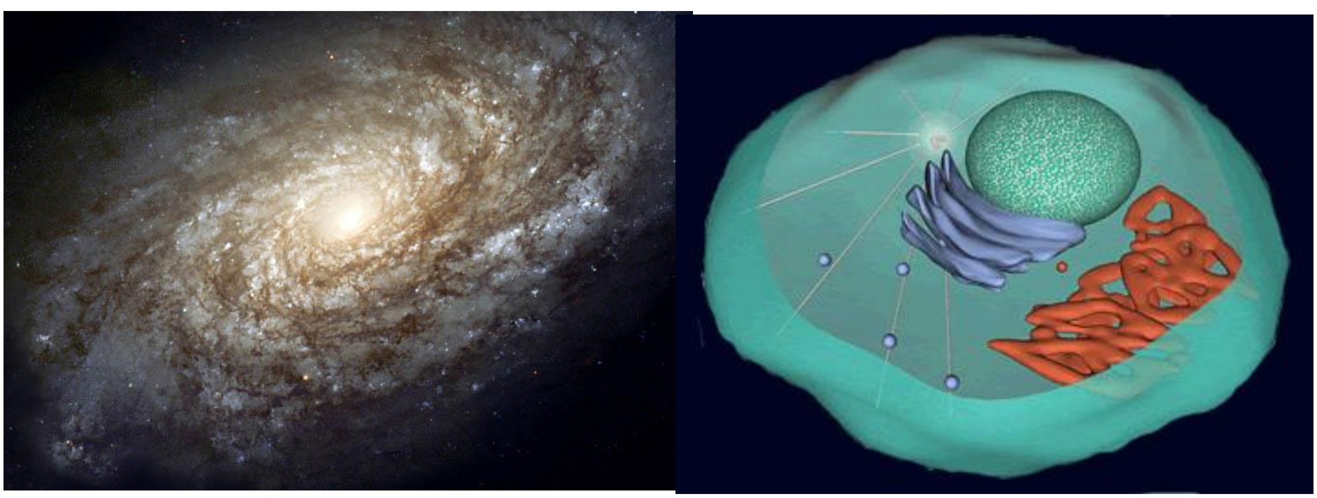


(caption) right photo[1]--one galaxy cluster swallowing another—an aggregation of roughly 10 trillion stars[2]
left photo[3]—one cell dividing in two—an aggregation of roughly 10 trillion atoms[4]

Abstract--Hamilton,[5] Trivers,[6] and their successors[7] made brilliant contributions to scientific insight. But it's time to put the selfish gene[8] in its place.[9] Evolution is less dependent on genetic difference and similarity than is generally perceived. In fact, evolution's most potent trait--the genesis of novelty--depends less than is usually imagined on organism and life. DNA replication is but a special case of something that began with

the big bang-- the Xerox Effect--the tendency of this cosmos to cough up copies in almost infinite abundance. Natural selection--the need to fit the environment's constraints--appeared in the Big Bang's earliest nanoseconds. Evolutionarily Stable Strategies have flourished since the first quarks joined in triumvirates. Variation and competition arose between gaseous macro-clusters long before the first ignition of the stars. Even proto-sociality and large-scale networking are long-standing cosmic legacies. Hamiltonian arithmetic is based on shared heritage, on family. When viewed in terms of protons, suns, and macromolecules, all bioforms are cousins in a single family tree. Planets, dust, and life-forms are all children of the Big Bang. Every living microbe, plant, or animal on Earth is a cousin in the clan of DNA. Every organism that ever was is a relative of its antagonists, of its food, and of the inanimate forces of complexifigenesis and catastrophe. A new way of framing questions and answers emerges when one sees Darwinism, the arithmetic of self interest, and the patterns of the human psyche in the broader context sketched by cosmology, astrophysics, particle physics, microbiology, and paleontology. In this light, it's time to reevaluate. What traits have we inherited from previous forms of life, and what traits have been bequeathed us by our pre-biotic ancestry?



(caption)[10] Astronomers refer to the heart of galaxies as nuclei.[11] Is this an appropriate use of biology's vocabulary? Or, to put it differently,
which aggregation of billions of constituent elements evolved the principle of central

control we call nucleation first—galaxies or cells?[12]

Evolution is a term used constantly these days by a breed of scientists who seldom if ever deal with the stuff of life—cosmologists, physicists, astrophysicists, and astronomers.[13] They use it to refer to galaxies, suns, and stars. The word "evolution" appears 191,787 times in *NASA's Astrophysics Data System, The Digital Library for Physics, Astrophysics, and Instrumentation* hosted by the Harvard-Smithsonian Center for Astrophysics. In other words, physicists and astrophysicists use the word evolution almost four times as often as they use the word "planet" (58,001 times).[14]

Are today's "hard scientists" applying the concept of evolution metaphorically? Are they misappropriating and misusing a term that rightfully belongs to only one form of cosmic interaction—the complex tangle we call life? No. Not at all.

Evolution depends on four factors[15]—reproduction,[16] competition, variation, and natural selection. All four factors existed in some form in the pre-biotic universe. All four started their twisting long before life began.

The universe started with a Big Bang,[17] not a whimper. Most of us acknowledge that by now.[18] What few of us realize is the capacity for duplication that this universe revealed literally within the first nano-flash of a second after its conception. The cosmos sprang from a convergence of infinities, a twist of crisscrossed nothings physicists call a singularity.[19] A sliver of a second[20] later more than 10^{88} protons[21] popped into being. Every one of these protons, no matter where or when it had appeared, was identical to every other—totally interchangeable. The same duplication happened with neutrons, electrons, positrons, and photons—or as the early families of particles are known—with all baryons and leptons.[22] Swarms so numerous they defy the human number system cascaded from a spreading sheet of space, time, and energy. All paid tribute to a dead-ringer-generating, identimorphic process of uncanny precision, a process churning out the very same pattern almost everyplace there was a place to be. Was this reproduction? No proton, so far as modern theory knows, ever begat another proton. Nor was this copycat imitation—the mechanism to which theorists like Susan

Blakemore[23] attribute the reproduction of memes. In our terms it was parallel or convergent evolution.

Evolution—isn't that an inappropriate, vitalistic term for the primordial plasma of an abiotic cosmos--one that wouldn't host a hint of life for another eleven billion years? The mistake, it seems, is made by the biocentric. Once again, evolution's essence as Charles Darwin saw it boils down to reproduction, variation, competition, and natural selection. Only one of these—reproduction--is a biological monopoly. And even that is a shade less clear-cut than it seems. Let's examine the pre-biotic cosmos for evolution's remaining trio, its triad of propulsive algorithms--variation, competition, and natural selection--one element at a time.

We have strong hints that natural selection has been with us since the earliest second of the Big Bang. Modern physics regards a universe as the product of a set of laws tweaked by roughly 20 variables.[24] What are natural laws? They dictate the way things can and cannot be. Violate the elemental laws, and you can't succeed. Even if you get away with overstepping the bounds for a picosecond or two, other products of natural law may eradicate you. As of 1999, atom smashers had generated roughly 300 forms of hopeful monsters—subatomic particles. Most disappeared within a trillionth of a trillionth of a second.[25] Only a handful could survive the rigors of this particular cosmos at this point in time.

This destruction of what doesn't fit is the ultimate punishment for "unnatural" crime. It's also the severest form of natural selection. What if the flash of the Big Bang had topped a particle accelerator in inanimate variation, in abiotic fecundity? What if it had precipitated 3,000, or three million hopeful genera of particles in its crack-up splat of energy?[26] How many of these early species of proto-matter have survived the fourteen billion years[27] or so since the instant that kick-started time? Only 72.[28] These 72 have made their way through a slew of natural selection's slings and arrows unparalleled by anything that breathes. They've endured the catastrophe of cosmic expansion, the disasters of galactic recompression, the eruption of stellar-center hells, the frigid chill of space, collision, contusion, explosion, intrusion, and the vagaries of ten billion years more time than any thing that ever rose from a mere twitch of RNA.

Natural selection worked with extreme ferocity in the first nanoseconds of the Big Bang and in the 300,000 years that followed.[29] The cataclysm physicist Alan Guth refers to as expansion[30] hit with a force that dwarfs the torment at the heart of a nuclear blast. Compression waves repeatedly crushed would-be particles together[31] in a squeeze that makes the mash at the heart of our sun seem like a day at the beach. The heat was beyond belief—it reached 10^{28} degrees Kelvin,[32] 10^{21} degrees hotter than the heart of the sun. Heat is a measure of speed. Which means that nanobits of primordial matter slammed each other with a destructive force that makes a collision of bullets seem like a polite meeting of snails for tea. Only 72 forms of elementary particle survived these ricochet-collisions. Only 72 abiotic species made it through this natural selectivity.

Even in this harshest of environments, the Xerox Principle worked its ways. Social aggregations by the sesquiviginquintillions gathered in identical patterns and showed their power to stay. They emerged as what Maynard Smith calls Evolutionarily Stable Strategies.[33] The triumphant micro-communities were protons, neutrons, and mesons.

- Protons were trios of a down quark and two up quarks.
- Neutrons had the opposite population—one up quark and two down.
- Mesons were quark duos—quarks in bonded pairs. [34]

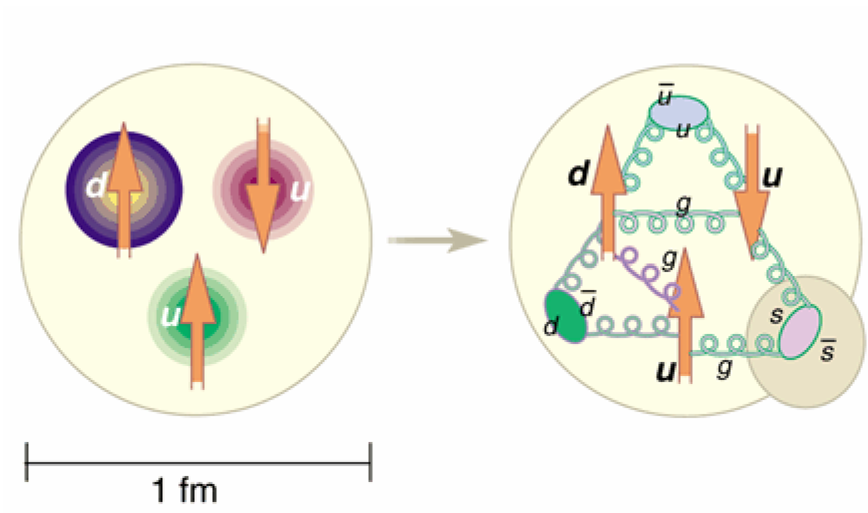
Despite crashes, smashes, violations, and attacks of outrageous kinds, these huddles of two and three have remained together since the first ten minutes of time. That's a form of fitness far beyond anything biomass has yet achieved. But perhaps these aggregations' strangest quality was is its strict adherence to precision and to the Xerox Principle—to identicality.

Another form of congregation made it through the brutal natural selectors that both early and recent environments tossed their way. A duplicative rain of neutrons precipitated in uncountable numbers[35] during the first slice of a second that formed the cosmos' first EEA.[36] Anthropocentric as it sounds, these neutrons were subjected to a critical social need. A neutron that paired with a proton could last almost eternally. A neutron that failed to find a proton partner in 10.6 minutes was doomed to disintegrate permanently. The forces of physics had literally built an apoptotic timer—a self-destruct mechanism—an **internal selector**[37]**-**into these wee monads of pre-life. The result? Three forms of nano-tribe or inanimate micro-family—

- Huddles of one or two neutrons around a single proton (progenitors of deuterium and tritium)[38]
- Clutches of two protons accompanied by one or two neutrons (the ancestors of helium)

- And clenches of three protons flanked by four neutrons (the future cores of lithium).

(Many protons stayed alone. These would someday form the core of hydrogen.)



(caption) A proton is a very social place. According to one current theory, a proton is a trio of quarks (left). According to another, it's more like a crowd of students in a phone booth—containing not only a quark threesome, but a pack of gluons and quark-antiquark pairs.[39] More to the point, despite the proton's intricacy,

the early universe spat out 10^{88} identical protons

in less than a second.[40] This cosmic habit of spontaneous—and often simultaneous--duplication is The Xerox Effect.

These monomorphic social coveys, too, made it through the slam-dance jam that physicists call a plasma—the superheated smash-em-up that filled the exploding space-time manifold like quivering molten lava for its first 300,000 years.[41] These duos and foursomes showed a power to succeed despite the pounding natural selection meted out even to pre-biotic breeds.

Then there's variation, the force of evolution Darwin admired the most and found it hardest to comprehend. That too appeared in the Big Bang's pre-biotic burst. Differentiation carved a chasm between highly distinctive forms:

- the matter-stuff called baryons (protons, neutrons, and their anti-matter counterparts)
- the smaller matter-bits called leptons (electrons, muons, tau particles, electron neutrinos, muon neutrinos, and tau neutrinos)
- and the force-carriers, the radiating, transporting, binding, and repelling particles (some of which are still quite hypothetical)—photons, gluons, W and Z particles, and gravitons.

Tossing another twist of variation into the early mix was yet another cleavage between kinds. This separation, this variation, is based on something we in psychology think of as a property that only biomass possesses—behavior, stimulus and response, action based on who's around you and on what your environment cues you to do. Fermions follow one rulebook of inanimate etiquette—that mapped out by Fermi-Dirac statistics. The cosmic directive fermions obey with strict obedience is this: if one fermion discovers that a nearby other has occupied a given quantum state, it may not crowd into the same quantum niche staked out by its companion. Instead it must assume a different quantum position.

The counterparts of fermions are bosons. These follow a different set of social do's and don'ts. The imperatives of bosons are described by Bose-Einstein statistics. These say that a flock of bosons can hop into the same quantum state and crowd together there quite comfortably.

The stimulus-response proclivities of fermions and bosons would not reveal their choreography until the universe was 300,000 years old. But with these social rules there would arise yet another critical evolutionary engine—competition. For at the year 300,000 ABB (After the Big Bang) the environment altered, and it altered drastically. Things cleared up and things slowed down. This was the second cosmic EEA. The scalding soup of bump-and-bash spread out. Particles downshifted from a slashing speed to a relative mosey of energy. Space opened in between the trios, duos, and quartets that formerly had crowded in a mash. Photons were no longer trapped in ricochet and for the first time were able to discover their propensity to travel in straight lines.[42] When humans would probe the cosmos fourteen billion years later, they'd sense these straight streams of photons as a subtle radiation, a glow that warms but sheds no light.[43]

Bosons were suddenly moved by new social cues. Protons found themselves reeled in by a force of a kind that had never shown itself in quite this way before. They were tugged toward nano-bits one 1,800th[44] their mass. And those tiny particles, electrons, responded to the tugging too. This led to a new circle-dance, a new form of nano-tribe or family. Electrons settled into shells around proton/neutron cores. And these orbiting electrons, being fermions, were polite to each other. No two crowded into the same quantum state. They aggregated yet kept a proper distance, revealing their obedience to the rules of inanimate *politesse* later traced by the mathematical courtesies mapped by Fermi and Dirac.

Thus did particles discover something observers—had there been some--would have found unbelievable. They gathered in the inanimate community we now take for granted and call "atoms." Once again, the Xerox Principle held sway. More identical gang-ups sprang up than our words for numbers—from trillions and octillions to duodecillians—can conveniently convey. And they did so not just one-by-one, but yoked in simultaneity.

If this were a random universe, innumerable social bundlings should have taken place—particle circles of five, ten, 20, or 30 protons and their neutron sidekicks. Theoretically there should have been mixes and matches—permutations and combinations—of all kinds. On the other hand, if this were the disintegrative universe of the entropists or the progress-less cosmos of the late Stephen Jay Gould, there should have been no social bundlings at all. But for the next few hundred million years, six and only six cluster patterns would thrive in the co-evolving environment of their time.[45] Only six would be generated by what Darwin labeled "variation." Only six would be favored by inanimate duplication. And only six would make it through the sieves of natural selection. The lucky winners were:

1. The perpetual swing of a single electron around a single proton—a tango held together by inanimate fascination.[46] This is the particle dance that we call hydrogen. Add a neutron to the center and the swirl's deuterium. Put a second neutron in, and the frisk is tritium.[47]

2. The swish of two electron circlers around the pivot of two protons and one or two neutrons. These are the particle gavottes we know as helium.[48]

3. The whip of three electrons around a hub of three protons and four neutrons. This is the whisk called lithium.

So evolutionarily stable were two of these atom-strategies, so mighty were their powers to overcome potential destroyers like the harsh smack of gamma rays, so hardened to bombardments of natural selectors-- that hydrogen and helium atoms passed the ultimate test of fitness—they make up 98% of the matter in this cosmos to this day.

Communal intersects of behaviors—of influenced-actions—were behind the startling new emergent properties atoms would display. Since this universe began there had been a mere three forces on display: the strong force, the weak force, and the electromagnetic. Yet there was another great bond-maker, one so weak that in the thickness of a plasma it had never once revealed its possibilities.[49] To an observer accustomed to what nature had been like for 300,000 years, it would have seemed a myth, a ghost, a fairy tale, a fantasy. This new emergent power would add to the Darwinian pistons of variation and selection another crucial evolutionary driver—competition. The force that slowly unveiled its strength now that the cosmos had calmed down a bit was the weakest of the four repellers and compellers. It was the sublets, yet the grandest of the basic socializers--gravity.[50]

Atoms existed but not substances. How could this be? No tug had yet emerged to pull atoms together in a wisp, a tad of dust, a heap. Let's put it bluntly. Without groups, there would have been no gravitational influence.[51] And without gravity, there would have been no atom mobs, no atom crowds and aggregations, and nothing to compete about.

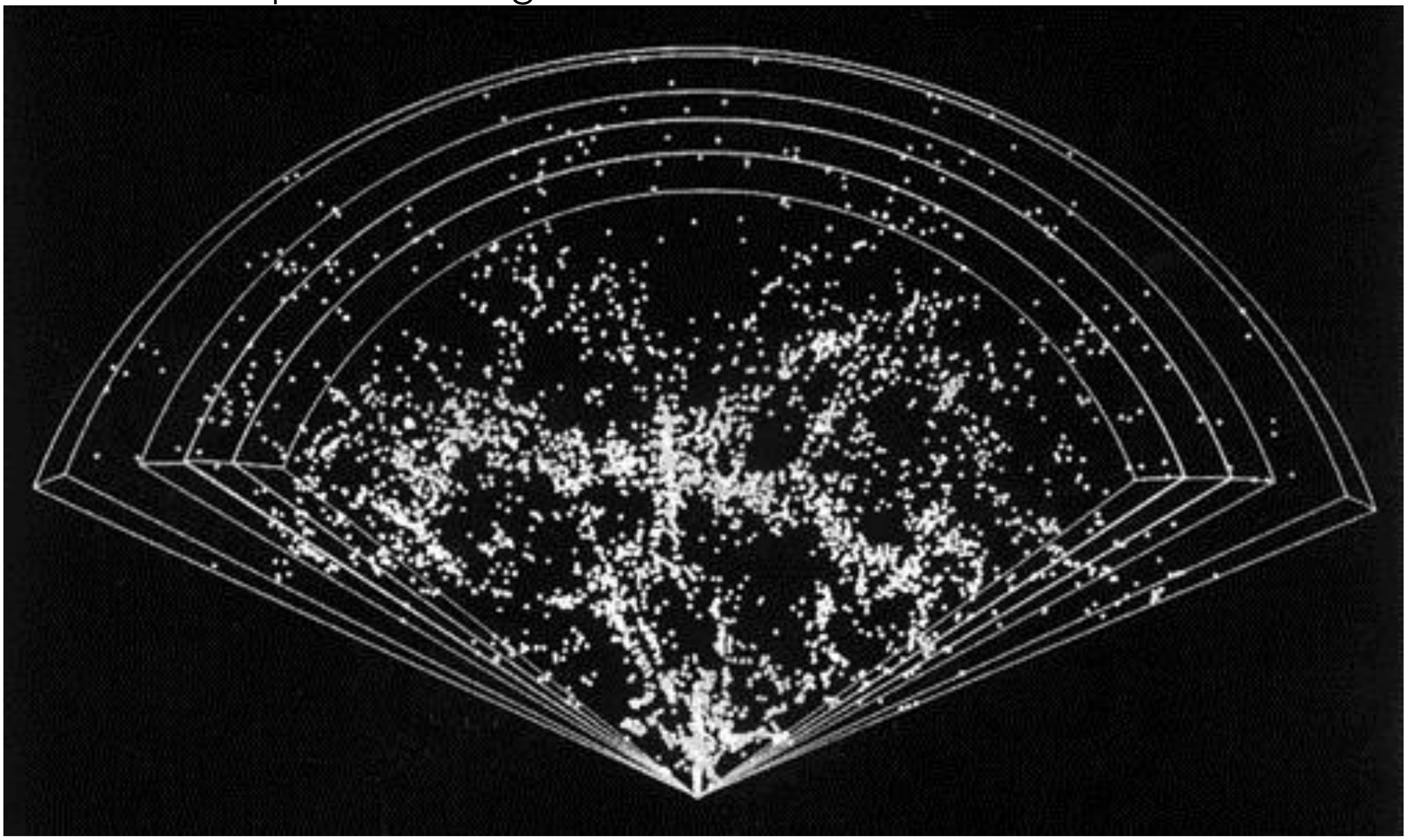
Cannibalism is the word astrophysicists and cosmologists use to describe the new, competitive gravity game.[52] Numbers were power—the more recruits you could attract, the more reinforcements you could dragoon. If your loosely flowing flock of hydrogen or helium atoms had more mass than that of a neighboring gas, you could swallow the wisp whole and add it to your atom congregation. If the multitude of atoms in your dust speck outnumbered the host in a rival fleck, you could haul in the less-populated squad then consume it using gravity's traction beam. The larger you got, the more neighbors you could attract or shanghai into your pack. When the big felt the attraction of the small, the large swept in the tiny and took all.

When wisps and specks were still brand new, the predatory[53] impact of their gravity would have seemed a piffle. But as atom-masses grew they changed the face of darkness, space and time. Long trails of queer, phantasm-stuff—matter-- threaded through the black of time and space.[54] Where they crossed[55] they battled to survive each others' tug.[56] Some hung together through sheer compromise. They swung in ellipses and spirals[57] around fattening hubs of gravitational stuff,[58] protected by their speed—by centrifugal force. They discovered yet another evolutionarily stable survival tactic—orbit[59]—a stratagem whose loops speckled the cosmic map.

This was the compromise. The atom-clots that stayed intact as circling captives added their tug to their motion-master's center of gravity. They upped the grasping power of the globular giant at the heart of their orbital course.

(caption) An act of what astronomers call galactic "cannibalism" and "predation."

The larger the gatherings of circlers and swallowers, the more new niches gravity carved out, and the more new forms and shapes its marauding masses showed. The globular atom-legions that reeled in rival squadrons turned to disks and whorls.[60] Pinprick specks evolved as pinwheels 100,000 light years across. These were the cinder-dark swirls of atoms we call galaxies. Groups of these megadishes duked it out for dominance. Tens of billions of galaxies were drawn together in superclusters that continue to attract and gorge on weaker neighbors to this day.[61] Competing clusters swept the space between them in their capture-matches. This lateral inhibition gave the new clumps spacing.[62] The mega-shapes[63] of circle-laced-with circle turned into an astro-froth,[64] a bubble-stuff [65] of mega-foam[66] whose particles are galaxies.[67]



(caption) A foam of galaxies. The spaces opened in this lace by gravitationally-powered lateral inhibition are between 60,000,000 to 150,000,000 light-years across.[68]

Gravitational sumo matches re-landscaped the flat plain of Einsteinian space/time. They gouged and raised the Van-Gogh patterns in our night-time sky.[69] Gravity was the great aggregator, the great integrator, the great pattern-maker of inanimate sociality. But as yet the sky was dark. Cosmic evolution hadn't yet discovered the secret of the spark.

Variation is a word too tame when something like surprise pops up and changes the very nature of the self-assembling[70] game. The crowding of atoms in the winning gravity centers created an atom smash.[71] Gravity balls grown overfat ignited.[72] They stripped their atom-inhabitants of electrons, mashed proton-neutron groups together—and forced these tortured families of particles to let go of energy. The loss flooded out as photons, and the radiating scatter of debris made light. Roughly 200 hundred million years after the Big Bang,[73] gravity's variation, natural selection, and competition had pricked through nature's blackness and had caused stars to ignite.

The Xerox effect—mass duplication—continued to adhere. The hulks that cracked their atoms and spilled photonic refugees were suns. Evolution cookie-cut them by the zillions, each in the shape of a sphere. The swirls in which hundreds of billions of suns were wheeled together by gravity were so profoundly similar that they're easily seen as galaxies. Thousands of herds of galaxies were corralled by gravity.[74] Yet despite their fantastic number, these clusters had a disk-shaped contour that remained at heart the same.[75] Stars, galaxies, and galaxy clusters all are evolutionarily stable strategies. All have proven their ability to endure nature's nightmares, her selectors, her evolution-honers, her gestation razors. All have triumphed over an environment of star-eat-star[76] and galaxy-eat-galaxy. And all have trillions of lookalikes. All have doppelgangers to the nth degree.

Repetition remained the rule for the next six billion years. Then once again the force Darwin calls variation coughed up a saltative change. Stars spun through developmental phases--youth, maturity, and, finally, old age. The leaping, rebel-jamming, atom-slam that powered stars ran out of energy. The liquid-like inferno at many a star's heart was squeezed. The core of the star shrunk down, grew cold, and balled up like a fist. Atomic nuclei at the heart grew sluggish and lost the energy to keep their distance, to stay apart. The stellar death-grip multiplied density and, in the presence of trapped nuclei,[77] gave that old attractive force new emergent properties.

> Catastrophe is opportunity in the world of evolution. Destruction spreads the seeds of new construction. During the years before the first stars died there had only been three basic atom-forms—hydrogen, helium, and lithium. All star-power, no matter where, had come from munching on hydrogen and helium nuclei. The stellar death-squeeze forced these ancient proton-neutron families to accept new social norms, to reluctantly ally in 89 new tribal forms.[78] Four protons forced together would be beryllium. Five protons tortured to unite would be boron. Six would be a wonder at match-making—carbon. Seven would be carbon's eventual sidekick, nitrogen. Eighty-eight would be the strange and flickery clan called radium.[79]^^

These were proton-neutron tribes created in the midst of supernova devastation. They were huddles, social strategies that would prove their stability in the worst starburst catastrophe this cosmos could toss at them. They were victors on the battlefield of natural selection.

The Xerox Effect—synchronicity, duplicative-evolution—the pre-biotic cousin of reproduction—still reigned. So much creativity, and yet so little change. So much novelty and yet so much constraint. Eighty-nine new atom-centers…yet in a world of 10^{77} protons,[80] so few. Why for every new atomic core would there be roughly 10^{55} carbon copies, 10^{55} dupes?

While old stars were dying, new stars were aborning—evolving by the trillions, yet self-assembling so identically they were indistinguishable as sheep. Star-wannabes self-seeded in patches where the matter-scraps were plenty, and battled nearby rivals gravitationally. Each scoured the dead-star bone yard for more-than-its-fair-share of debris. In the clutter that they sucked up there was something new--a smattering of the novel newborn atoms. These were the 89 freshly-scrunched crews of protons and of neutrons—the new elements the rules of duplicative generation, competition, gravitation, and selection had sutured in new forms of sociality.

In the new stars' wakes, inanimate evolution produced another newness unknown in this cosmos' first few hundred million (and possibly even billion) years—radical new **molecules**.[81] Raucous jumbles of atom-combinations explored their possibilities.[82] They spat out biomolecules in multitudes,[83] the product of chance and of emergent opportunity. Yet hydrogen and helium were still the rule. Hydrogen and helium, the oldsters in the evolutionary match of slam, crash, join-together, and dance, have shown a hardiness, a fitness, an ability to take on comers of all kinds and stick together. They are still 98% of all we know as gas and matter.

The epoch of new-star-and-matter-birth was the third great era of the EEA. All throughout the cosmos nucleic acids, ammonia, and sugars crystallized on spicules of amorphous ice,[84] clumped in slush-and-dustball comets, and discovered their fraternity while mix-and-matching in the stuff of meteorites.[85] Without replication there was iteration. Carbon-copy molecules[86] precipitated with precise identicality billions of light years from each other in the emptiness of space. If any found a planet or a moon with liquid water they could do a dance of conjugation and gather in a bubble, in an empty pocket that invited filling. Yes, when plunked into a puddle of water, meteorite-born polyols, dihydroxyacetones, glycerols, sugar acids, and sugar alcohols automatically swarm together in the lipid-like-bubble we now call a membrane.[87]

On one planet that we know of, these new proton-neutron-and-electron aggregations flocked in yet far larger mass confederations—complex, varied, polyglotted atom-leagues, knotted ropes of atoms stitched by strange affinities.[88] Repetitious cables of atom-squadrons seduced and recruited[89] nitrogenous and hydrogenous outriders to join on their periphery. These were the shockingly "unnatural" new mass behaviors, the whole new ways of hanging out together, the whole new strategies in which particles by the millions joined to make it through a rain of insults—heat and iceballs,[90] ultraviolet rays, the shock of planetesimals splattering the globe on which they rode, and high-speed particles slammed down from space.[91] In the flick of less than 750 million years,[92] these new strings, new tangles, rings, and triangles of particles uncovered a bizarre new opportunity[93]—the ability to fuse and flicker in the huge self-replicating armies of atom-scavengers that we call DNA. Every living creature, from bacteria to salamander and to all of us now in this room—are children of this history. We are the offspring of this self-creating, self-evolving cosmos that's crawled upward despite the grand disintegrator, entropy. We are mounds of quarks in trios, we are proton-and-electron families. We are children of a repetition, an iterative churning that cookie-cuttered with identical precision long before there was a thing called breathing or the spasm of 100 trillion human cells we call a sneeze.

Evolution has crept forward since the first twitch of inflation from a singularity. And so have social strategies. We are the Big Bang's children. We are containers of the Xerox Principle's legacy. There is only one life-process on this planet, not the 30 or 3,000 we'd expect if evolution had proceeded in blind randomness. This cosmos can create but is constrained. There are only 92 natural forms of atoms, not the millions that a random cosmos would gestate. There is but a single family on this planet, just one life-form stretching out its tendrils, testing possibilities as dust and stars did once upon a time. Face it, we are all in this together, microbes,[94] seaweed, starfish, salamanders, humans, every strange extrusion of nucleic acid chains.[95] We are the kin of yeast, the brothers of cockroaches, the sisters of sugar beets, and the cousins of maize.[96] We share a common birthright born of ancient gene-and-membrane teams. All of us are children in the clan of DNA.

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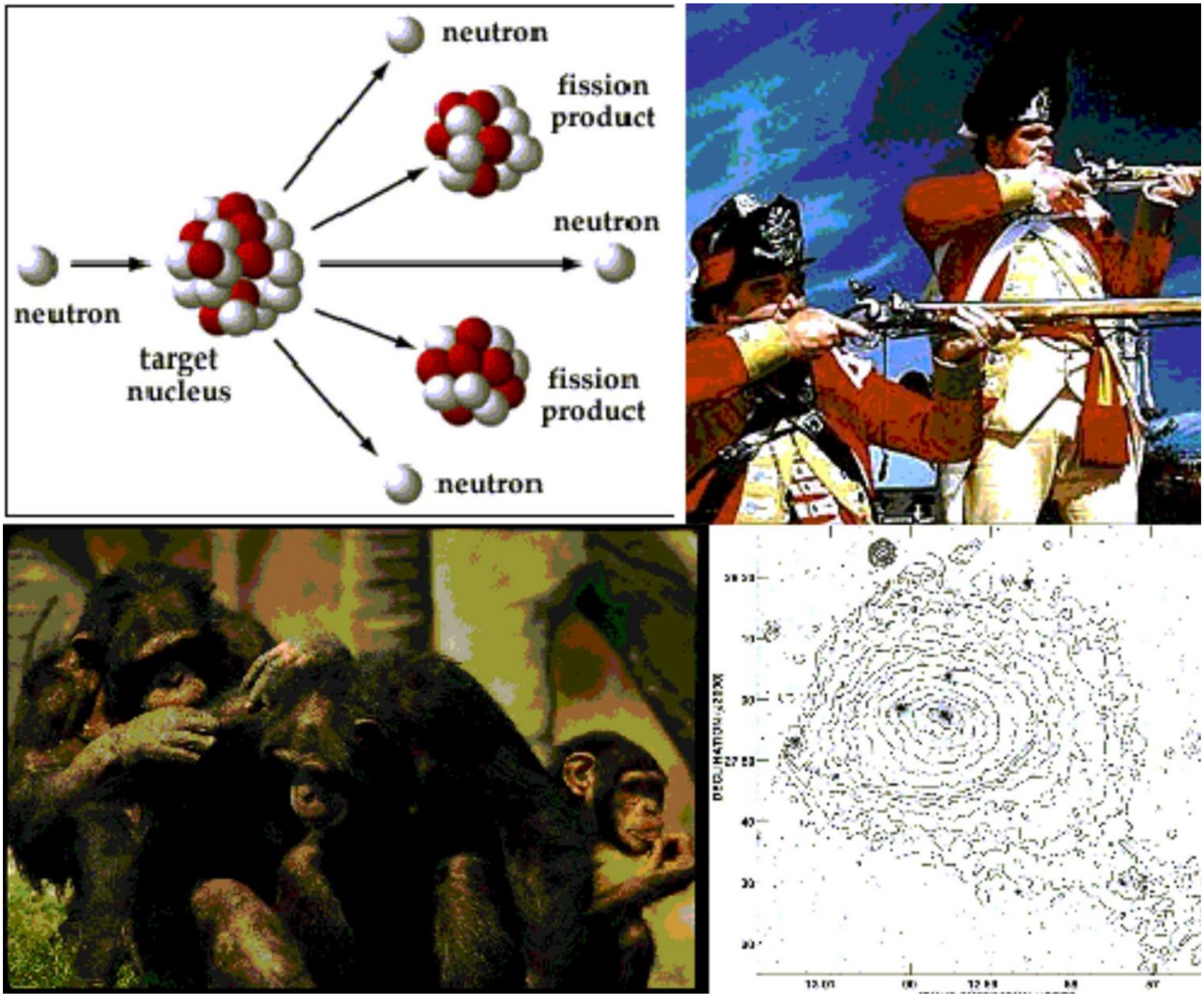

(caption)

Fission and fusion started in the big bang.

They appeared in the formation of baryons, in the disintegration of neutrons, in the birth of proto-galaxies, and in the ignition and death of stars. They've led to aggregations as small as protons and atoms and as large as galaxy superclusters. Fission and fusion also took place among biomolecules, bacteria, plants, animals, and human clans, and led to aggregations as small as proteins and as large as empires and nations. Which first pioneered fission and fusion strategies--protons and galaxies, or bacteria, chimps, and human beings?

Are fission and fusion examples of evolutionarily stable strategies, or are they simply sloppy similes?

[97] (Illustrations clockwise from upper left: nuclear fission,[98] the fission of The United States of America from its parent body, Britain,[99] a moment of fusion among chimpanzees,[100] and a moment of fusion between two clusters containing several thousand galaxies.[101])

NOTES

[1] Photo credit: from the Digital Sky Survey, "X-ray, optical, and radio overlays of two [galactic] clusters." The photo appeared in: Science Volume 280, Number 5362 Issue of 17 Apr 1998.

[2] Jack O. Burns. Stormy Weather in Galaxy Clusters. *Science*, Volume 280, Number 5362,17 Apr 1998: 400 – 404.

[3] Photo credit: Biodidac. Histology, "Amphibia- Ambystoma- Ambystoma larval epidermis WM FeH x10019-3 B1 Cell Division Mitosis Metaphase: equatorial plate" Retrieved June 2, 2002, from the World Wide Web http://biodidac.bio.uottawa.ca/Thumbnails/histocatquery.htm

[4] There are 300 million molecules in the average bacterial cell…if you don't count the water. Add in the H_2O, multiply by 100 to get the volume of water in a small eukaryotic cell, then calculate an average of 100 atoms per biomolecule. You arrive at ten trillion atoms per cell. Even that figure is likely to be an understatement. (Franklin M. Harold [2001]. The Way of the Cell: Molecules, Organisms and the Order of Life. NY: Oxford University Press: 10.)

[5] R. Axelrod, & W.D. Hamilton (1981). The evolution of cooperation. Science, 211, 1390-1396; W.D. Hamilton (1964). The genetical evolution of social behavior, I and II. Journal of theoretical biology, 7, 1-52. W.D. Hamilton (1991). Selection of selfish and altruistic behavior in some extreme models. In J. S. Eisenberg, & W. S. Dillon (Ed.), Man and beast:

Endonotes continued on back…

comparative social behavior (pp. 57-92). Washington D.C.: Smithsonian Institution Press.

[6] R.L. Trivers (1971). The evolution of reciprocal altruism. Quarterly Review of Biology, 46, 35-57. R.L. Trivers (1985). Social evolution. Menlo Park, CA: Benjamin/Cummins.

[7] G. Williams (1966). Adaptation and natural selection. Princeton, NJ: Princeton University Press. M. Daly & M. Wilson (1988). Homicide . New York: Aldine de Gruyter; J. H. Barkow, L. Cosmides, & J. Tooby (1992). The adapted mind: evolutionary psychology and the generation of culture. Oxford: Oxford University Press; R. Axelrod (1980). Effective choices in the prisoner's dilemma. Journal of Conflict Resolution, 24, 3-25. R. Axelrod (1980). More effective choices in the prisoner's dilemma. Journal of Conflict Resolution, 24, 379-403; R. Boyd, & P.J. Richerson (1980). Effect of phenotypic variation on kin selection. Proceedings of the national academy of sciences, 77, 7506- 7509. R. Boyd & P.J. Richerson (1982). Cultural transmission and the evolution of cooperative behavior. Human Ecology, 10, 325-351. R. Boyd & P.J. Richerson (1985). Culture and the evolutionary process . Chicago: University of Chicago Press. C. Boehm (1981). Parasitic selection and group selection: a study of conflict interference in rhesus and Japanese macaque monkeys. In A. B. Chiarelli, & R. S. Corruccini (Ed.), Primate behavior and sociobiology (pp. 161-82). Berlin: Springer-Verlag R. Boyd & P.J. Richerson (1988). The evolution of reciprocity in sizable groups. Journal of Theoretical Biology, 132, 337-356. R. Boyd & P.J. Richerson (1989). The evolution of indirect reciprocity. Social Networks, 11, 213-236; L. Buss (1987). The evolution of individuality . Princeton, NJ: Princeton University Press; David M. Buss. *The Evolution of Desire--Strategies of Human Mating*. New York: Basic Books, 1994. David M. Buss. *Evolutionary Psychology: The New Science of the Mind*. Boston, MA: Allyn and Bacon, 1999. Randolph M. Nesse, M.D. and George C. Williams, Ph.D., *Why We Get Sick: The New Science of Darwinian Medicine*. New York: Random House, 1995. Cosmides, L., & Tooby, J. (1987). From evolution to behavior: evolutionary psychology as the missing link. In J. Dupre (Ed.), The latest on the best: essays on evolution and optimality (pp. 277-307). Cambridge, Mass: Bradford (MIT Press). H. Cronin (1991). The ant and the peacock: Altruism and sexual selection from Darwin to today. Cambridge: Cambridge University Press. Richard Dawkins. *The Extended Phenotype: The Long Reach of the Gene*. Oxford: Oxford University Press, 1982; L. Cosmides & J. Tooby (1997). Evolutionary Psychology: A Primer. Santa Barbara: Center for Evolutionary Psychology, University of California. Retrieved June 1999 from the World Wide Web: http://www.clark.net/pub/ogas/evolution/EVPSYCH_primer.htm

[8] Richard Dawkins. *The Selfish Gene*. New York: Oxford University Press, 1976.
[9] Elliott Sober and David Sloan Wilson. *Unto Others: The evolution and psychology of unselfish behavior*. Cambridge MA: Harvard University Press, 1988; C Boehm (1982). A fresh look on cultural selection [review article on 'Programmed to learn: an essay on the evolution of culture', by H.R. Pulliam and C. Dunford and 'Population pressure and cultural adjustment', by V. Abernethy bibliogr.] American anthropologist. 84:1 pp 105-25. Christopher Boehm (1996). Emergency decisions, cultural-selection mechanics, and group selection Current anthropology. 37:5 pp 763-93. Boyd, R., & Richerson, P. J. (1988). The evolution of reciprocity in sizable groups. Journal of Theoretical Biology, 132, 337-356. Boyd, R., & Richerson, P. J. (1989). The evolution of indirect reciprocity. Social Networks, 11, 213-236; L.A. Dugatkin, M. Mesterton-Gibbons. "Cooperation among unrelated individuals: reciprocal altruism, by-product mutualism and group selection in fishes." *Bio Systems*. v 37 n 1, 1996; Christopher Boehm. "Four Mechanical Routes To Altruism." March, 1996, pre-publication draft. Goodnight, C. J. (1990). Experimental studies of community evolution I: The response to selection at the community level. Evolution, 44, 1614-1624. Goodnight, C. J. (1990). Experimental studies of community evolution II: The ecological basis of the response to community selection. Evolution, 44, 1625-1636
[10] Photo credit: athttp://chandra.harvard.edu/press/press_102599.html. Extended X-Ray Jet In Nearby Galaxy Reveals Energy Source. Chandra X-Ray Observatory Center (http://chandra.harvard.edu) Date: Posted 10/28/99.
[11] Julian Henry Krolik (1998). Active Galactic Nuclei: From Central Black Hole to the Galactic Environment. Princeton: Princeton University Press; Daniel W. Weedman. Making Sense of Active Galaxies. Science, Volume 282, Number 5388 Issue of 16 Oct 1998, pp. 423-424; Richstone, D.O., et al. 1997. Meeting of the American Astronomical Society. Toronto, Ontario. Evidence for A 20 Parsec Disk at the Nucleus of Centaurus A. Author(s)Schreier, Ethan J. Marconi, Alessandro Packham, Chris The Astrophysical journal, June 01 1998 v 499 n 2 p 2 Space Telescope Science Institute, http://oposite.stsci.edu/pubinfo/pr/1998/14/pr.html, downloaded August 1999 PR98014 14 May 1998 Hubble Provides Multiple Views of How to Feed a Black Hole
[12] For the validity of isomorphing one cosmic pattern onto another—or an astronomical pattern on to a biological pattern, see Science Volume 274, Number 5287 Issue of 25 Oct 1996, pp. 524 - 525 Duality in Perspective S. M. Girvin: "Duality transformations are mathematical methods that relate the physical properties of one system to those of another, possibly very

different, physical system. If such a transformation exists, the systems are said to be dual to each other."

[13] For particularly good examples of evolutionary terminology used in astrophysics, see: Lee Smolin. 1997. The Life of the Cosmos. New York: Oxford University Press. Martin Rees. Before the Beginning: Our Universe and Others (1997). Reading, Massachusetts: Perseus Books.

[14] Among other things *NASA's Astrophysics Data System* provides a reference to the 35 top journals in astrophysics and astronomy. The NASA Astrophysics Data System: The Digital Library for Physics, Astrophysics, and Instrumentation Harvard-Smithsonian Center for Astrophysics. Retrieved August 30, 2018, from the World Wide Web http://adsabs.harvard.edu/cgi-bin/nph-abs_connect?db_key=AST&db_key=INST&db_key=PHY&db_key=PRE&aut_xct=NO&aut_logic=OR&author=&start_mon=&start_year=&end_mon=&end_year=&ttl_logic=OR&title=&txt_logic=OR&text=evolution%0D%0A&nr_to_return=3000&start_nr=1&start_entry_day=&start_entry_mon=&start_entry_year=&min_score=&jou_pick=ALL&ref_stems=&data_and=ALL&sort=SCORE&aut_syn=YES&ttl_syn=YES&txt_syn=YES&aut_wt=1.0&ttl_wt=0.3&txt_wt=3.0&aut_wgt=YES&ttl_wgt=YES&txt_wgt=YES&ttl_sco=YES&txt_sco=YES&version=1 http://adswww.harvard.edu/

[15] In his *Origin of Species*, Darwin characterized these factors as "variation" (a term he used 125 times and on which he based three chapter titles); inheritance (a term he uses in various forms over 168 times), "struggle" or "struggle for existence" (88 times), and, of course, "natural selection" (539 times). Tooby and Cosmides reduce evolution to two factors: "The evolutionary process has two components: chance and natural selection." By this standard, even the factor of reproduction or duplication isn't necessary for the evolutionary process to take effect. Cosmides, L. & Tooby, J. (1997). Evolutionary Psychology: A Primer. Santa Barbara: Center for Evolutionary Psychology, University of California. Retrieved June 1999 from the World Wide Web: http://www.clark.net/pub/ogas/evolution/EVPSYCH_primer.htm. Numerous basic courses on evolution include the four factors. For examples see: Douglas J. Eernisse, Biology 404 Home Page, Department of Biological Science, California State University, Fullerton http://biology.fullerton.edu/courses/biol_404/web/rq/ue_ch01.htm; and Jon A. Baskin, Ph.D.
Professor-Biology, Texas A&M University, Kingsville, TX. http://users.tamuk.edu/Jon.Baskin/Biology/EVOLUTION/b3301_ch003.htm Charles Darwin. *Origin of Species*. In *Library of the Future*, 4th Edition, Ver. 5.0. Irvine, CA: World Library, Inc., 1996. CD-Rom.

[16] "differential reproduction (and not survival per se) is the engine that drives natural selection." Cosmides, L. & Tooby, J. (1997). Evolutionary Psychology: A Primer. Santa Barbara: Center for Evolutionary Psychology, University of California. Retrieved June 1999 from the World Wide Web: http://www.clark.net/pub/ogas/evolution/EVPSYCH_primer.htm

[17] Modern Big Bang Theory was introduced in: George Gamow, Ralph Alpher, and H. Bethe (1948). "The Origin of Chemical Elements" *The Physical Review*, 73, 803. See also: Weinberg, S. The First Three Minutes: A Modern View of the Origin of the Universe, upd. ed. New York: Basic Books, 1988.

[18] Peebles, P.J.E. 1998. Is cosmology solved? Nature of the Universe Debate: Cosmology Solved? October. Washington, D.C. Turner, M.S. 1998. Cosmology solved? Quite possibly! Nature of the Universe Debate: Cosmology Solved? October. Washington, D.C. The Greatest Story Ever Told Is cosmology solved? By RON COWEN-- Science News, Vol. 154, No. 25 & 26, December 19 & 26, 1998, p. 392. Just like every scientific concept, including evolution, Big Bang theory remains a hypothesis subject to continual testing and dispute. However every piece of evidence in the last few decades that's made headlines by purporting to disprove the Big Bang theory has proven wrong.

[19] S. W. Hawking's, R. Penrose (1970). 'The Singularities of Gravitational Collapse and Cosmology,' Proceedings of the Royal Society of London A, 314: 529-548.

[20] Figures on the size of the slice of a second in which elementary particles emerged range from 10^{-34} through 10^{-31}.

[21] Jeremy Bernstein (1995). *An Introduction to Cosmology*. Englewood Cliffs, NJ: Prentice Hall: 12-14; Edward L. Wright. "Brief History of the Universe." Astronomy Department, UCLA. Retrieved August 30, 2018, from the World Wide Web http://www.astro.ucla.edu/~wright/BBhistory.html. G.H. Hardy (1999) *Ramanujan: Twelve Lectures on Subjects Suggested by his Life and Work*. New York: Chelsea.

[22] Allday, J. *Quarks, Leptons, and the Big Bang*. IOP Press, 1998. Bergstrom, L. and Goobar, A. *Cosmology and Particle Astrophysics*. New York: Wiley, 1999.

[23] Susan Blackmore, Richard Dawkins (1999). The Meme Machine. Oxford: Oxford University Press.

[24] Lee Smolin. (1997). The Life of the Cosmos. New York: Oxford University Press: 37.

[25] Curt Suplee (1999). *Physics in the 20th Century*. NY: Abrams: 142-145.

[26] This sentence may understate the initial variety of particles propelled into being by the first burst of the Big Bang. One science writer, Ron

Cowen, reported from the October, 1998 "Nature of the Universe Debate: Cosmology Solved?" at the Smithsonian Institution's National Museum of Natural History in Washington, D.C. that during "the earliest, fiery moments of the universe, …high temperatures would have set the stage for the creation of a vast zoo of elementary particles." The Greatest Story Ever Told Is cosmology solved? By RON COWEN-- Science News, Vol. 154, No. 25 & 26, December 19 & 26, 1998, p. 392.

27 The fourteen billion year age of the universe is still somewhat conjectural, but it has been confirmed within a margin of error of two billion years by such papers as Alexei V. Filippenko's groundbreaking "Einstein's Biggest Blunder? High-Redshift Supernovae and the Accelerating Universe": Alexei V. Filippenko. Einstein's Biggest Blunder? High-Redshift Supernovae and the Accelerating Universe. American Physical Society, April Meeting, Jointly Sponsored with the High Energy Astrophysics Division (HEAD) of the American Astronomical Society, April 20-23, 2002, Albuquerque Convention Center Albuquerque, New Mexico, Publication Date: 04/2002.

28 The great subatomic survivors of inanimate natural selection number roughly 72. Current theory pinpoints six leptons: the electron; the muon; the tau particle; the electron neutrino, the muon neutrino, and the tau neutrino. The carriers of the four forces (gravity, electromagnetism, the strong force, and the weak force) are hypothesized to be the gluon, the W and Z particles, and the graviton. Then there are the six quarks: up, down, charm, strange, top, and bottom. Finally, there are another 17 "stable hadrons"—hadrons with half-lives so brief that they vary from 10^{-8} to 10^{-20} seconds. If you count the anti-matter equivalents of each of the particles listed above, the total number of subatomic particle survivors comes to roughly 72.

The nearly infinitesimal life-span of seventeen of the "stable hadrons" indicates that these short-lived particles are, indeed, evolutionarily stable strategies. Though they disappear almost instantly, they've reappeared persistently from the beginning of the universe until today.

Another note, protons and neutrons are actually "social" aggregations--trios of quarks. Mesons are also aggregations--duos of quarks. Or, to put it in the words of physicist Günther Rosner, "neutrons and protons are not elementary but are composite particles." Günther Rosner (2000). How Strange Is the Proton? *Science,* Volume 290, Number 5499, Issue of 15 Dec 2000, pp. 2083-2084. Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/content/full/290/5499/2083?maxtoshow

=&HITS=10&hits=10&RESULTFORMAT=&fulltext=%2Bquark+%2Bproton&searchid=1022973810519_6209&stored_search=&FIRSTINDEX=0&fdate=10/1/1995&tdate=5/31/2002

[29] Peter Coles (1998). The end of the old model Universe. *Nature*, June 25, 1998, 393: 741 – 744; Ron Cowen (1998). "The Greatest Story Ever Told: Is cosmology solved?" *Science News*, Vol. 154, No. 25 & 26, December 19 & 26, 1998: 392. Ron Cowen (2001). Sounds of the universe confirm Big Bang. *Science News,* April 28, 2001; Vol. 159, No. 17. Retrieved April 30, 2001, from the World Wide Web http://www.sciencenews.org/20010428/fob3.asp; Lawrence Berkeley National Laboratory (2001). Scientists Unveil High Resolution Picture Of The Early Universe. Reprinted from ScienceDaily Magazine Date Posted: Thursday, May 3, 2001 Retrieved May 3, 2001, from the World Wide Web http://www.sciencedaily.com/releases/2001/05/010501074548.htm; Eugenie Samuel. Seeds of the first galaxies glimpsed. NewScientist.com 24 May 02, Retrieved August 30, 2018, from the World Wide Web http://www.newscientist.com/news/print.jsp?id=ns99992322; N.W. Halverson; E.M. Leitch; C. Pryke; J. Kovac; J.E. Carlstrom; W.L. Holzapfel; M. Dragovan; J.K. Cartwright; B.S. Mason; S. Padin; T.J. Pearson; A.C.S. Readhead; M.C. Shepherd (2002). Degree Angular Scale Interferometer First Results: A Measurement of the Cosmic Microwave Background Angular Power Spectrum. The Astrophysical Journal, March 2002 Volume 568, Issue 1, pp. 38-45. Retrieved August 30, 2018, from the World Wide Web http://adsabs.harvard.edu/cgi-bin/nph-bib_query?bibcode=2002ApJ...568...38H&db_key=AST&high=3ce5646fdb06099; National Science Foundation. Microwave Imager Probes Universe "First Light" To Answer Cosmological Questions. Reprinted from ScienceDaily Magazine. Retrieved August 30, 2018, from the World Wide Web.

[30] Alan H. Guth. "Inflation." Proceedings of the National Academy of Sciences, June 1, 1993: 4871-4877. Alan H. Guth. The inflationary universe: the quest for a new theory of cosmic origins. Reading, MA: Addison-Wesley, 1997.

[31] Christopher J. Miller, Robert C. Nichol, and David J. Batuski (2001). Acoustic Oscillations in the Early Universe and Today. *Science* June 22, 2001, 292: 2302-2303; Retrieved May 31, 2002, from the World Wide Web http://www.sciencemag.org/cgi/content/full/292/5525/2302?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&author1=Miller%2C+C.&searchid=1022880858069_13253&stored_search=&FIRSTINDEX=0&fdate=4/1/2001&tdate=6/30/2001

32 Edward L. Wright. "Brief History of the Universe." Astronomy Department, UCLA. Retrieved May 28, 2002, from the World Wide Web http://www.astro.ucla.edu/~wright/BBhistory.html.
33 John Maynard Smith (1982). Evolution and the theory of games. Cambridge: Cambridge University Press.
34 "subatomic particle" Encyclopædia Britannica. Retrieved August 30, 2018, from the World Wide Web http://www.britannica.com/eb/article?eu=115244. Günther Rosner (2000). How Strange Is the Proton? *Science,* Volume 290, Number 5499, Issue of 15 Dec 2000, pp. 2083-2084. Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/content/full/290/5499/2083?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&fulltext=%2Bquark+%2Bproton&searchid=1022973810519_6209&stored_search=&FIRSTINDEX=0&fdate=10/1/1995&tdate=5/31/2002
35 Actually, the number of neutrinos produced in the big bang would have been roughly 10^{87}—1/6th the number of protons.
36 "the environment of evolutionary adaptedness, or EEA, is not a place or time. It is the statistical composite of selection pressures that caused the design of an adaptation." Leda Cosmides and John Tooby (1997). *Evolutionary Psychology: A Primer*. Santa Barbara: Center for Evolutionary Psychology, University of California. Retrieved June 1999 from the World Wide Web: http://www.clark.net/pub/ogas/evolution/EVPSYCH_primer.htm
37 For the role of apoptotic internal selectors at nearly all levels of life, from unicellular to human, see Howard Bloom *The Lucifer Principle: A Scientific Expedition Into the Forces of History* (in which internal selectors are called self-destruct mechanisms) and *Global Brain: The Evolution of Mass Mind From The Big Bang to the 21st Century* (in which internal selectors are called "inner-judges").
38 Many protons stayed alone. These would someday form the core of hydrogen. Alan H. Guth. *The inflationary universe: the quest for a new theory of cosmic origins*. Reading, MA: Addison-Wesley, 1997: 91, 330.
39 Proton diagram and data: Günther Rosner (2000). How Strange Is the Proton? *Science,* Volume 290, Number 5499, Issue of 15 Dec 2000, pp. 2083-2084. Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/content/full/290/5499/2083?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&fulltext=%2Bquark+%2Bproton&searchid=1022973810519_6209&stored_search=&FIRSTINDEX=0&fdate=10/1/1995&tdate=5/31/2002

[40] Raghavan Rangarajan, D.V. Nanopoulos. Inflationary baryogenesis. *Physical Review D (Particles, Fields, Gravitation, and Cosmology)*, Volume 64, Issue 6, 15 September 2001.
[41] Storm Dunlop. "Boom...hiss." *New Scientist*, July 12, 1997. Retrieved August 30, 2018, from the World Wide Web http://www.newscientist.com/lastword/answers/363universe.jsp?tp=universe2. Eugenie Samuel. Seeds of the first galaxies glimpsed. NewScientist.com, May 24, 2002 Retrieved May 24, 2002, from the World Wide Webhttp://www.newscientist.com/news/print.jsp?id=ns99992322.
[42] National Science Foundation. Microwave Imager Probes Universe "First Light" To Answer Cosmological Questions." Posted: Friday, May 24, 2002 Reprinted from ScienceDaily Magazine, Retrieved May 24, 2002 from the World Wide Web http://www.sciencedaily.com/print/2002/05/020524073132.htm.
[43] The Cosmic Microwave Background, a 3 degree-Kelvin thermal radiation for whose discovery Arno Penzias and Robert Wilson of Bell Labs won the 1978 Nobel Prize for Physics.
[44] There is a more precise figure for the difference in mass between a towering proton and a flea-like electron. The proton is 1,836.15 as massive as an electron. Proton. Eric Weisstein's World of Physics. Wolfram Research. Retrieved August 30, 2018, from the World Wide Web http://scienceworld.wolfram.com/physics/Proton.html
[45] Alan H. Guth. The inflationary universe: the quest for a new theory of cosmic origins. Reading, MA: Addison-Wesley, 1997: 91.
[46] Newton's early interpreters called this sort of inanimate fascination "attraction at a distance." Had we not been inured by 300 years of usage to this terminology, the word "attraction" might seem to us a sinful use of anthropomorphism. (John Henry "'Pray do not ascribe that notion to me': God and Newton's Gravity", in *The Books of Nature and Scripture: Recent Essays on Natural Philosophy, Theology and Biblical Criticism in the Netherlands of Spinoza's Time and the British Isles of Newton's Time*, edited by James E. Force and Richard H. Popkin (Kluwer Academic Publishers, Dordrecht, 1994), pp. 123-47. Retrieved August 30, 2018, from the World Wide Web http://homepages.ed.ac.uk/sociol/Research/Staff/henry_pray.htm.)
[47] The Columbia Encyclopedia, Fifth Edition Copyright _1993, Columbia University Press.
[48] The Macmillan Encyclopedia 2001, © Market House Books Ltd 2000
[49] Technically, gravity played a role in the first inflationary flick of the cosmos' birth, but it was a massive repulsive force, not the great attractor we know today. For more on gravity's explosive role in the first instants of

the universe and then this explosive gravity's rapid decay, see: Alan H. Guth. Genesis: The Sequel. *Natural History*, Feb, 2000: 77-80. For gravity's later role in shaping the large-scale structures of the cosmos we know today, see: Suzanne Staggs. What the Cosmic Microwave Background Reveals about the Past, Present and Future of the Universe. American Physical Society, April Meeting, Jointly Sponsored with the High Energy Astrophysics Division (HEAD) of the American Astronomical Society April 20 - 23, 2002 Albuquerque Convention Center Albuquerque, New Mexico, Publication Date: 04/2002

[50] "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

[51] Gravity's "influence" is another anthropomorphic term Newton has inured us to.

[52] NASA's Astrophysics Data System lists the use of the term cannibalism in 109 journal articles and meeting abstracts.

[53] The term "predator" may seem unscientific and biocentric, but such "anthropomorphic" terminology has become normal among today's astrophysicists. The term "predatory" shows up 131 times in the journal articles and meeting abstracts indexed by NASA's Astrophysics Data System.

[54] Carlos S. Frenk, August E. Evrard, Simon, D.M. White, F.J. Summers (1996). Galaxy Dynamics in Clusters. *Astrophysical Journal*, 12/1996, v.472, p.460; Gopal-Krishna, Paul J. Wiita. Was the Cosmic Web of Protogalactic Material Permeated by Lobes of Radio Galaxies During the Quasar Era? The Astrophysical Journal, October 2001, Volume 560, Issue 2, pp. L115-L118.

[55] D. Pogosyan; J.R. Bond, L. Kofman, J. Wadsley. The Cosmic Web and Filaments in Cluster Patches. Bulletin of the American Astronomical Society, January 1996, Vol. 28: 1289: Dick Bond, Lev Kofman, Dmitry Pogosyan, James Wadsley (1998). Theoretical Tools for Large Scale Structure. Wide Field Surveys in Cosmology, 14th IAP meeting held May 26-30, 1998, Paris. Editions Frontieres, 1998: 17; Space Telescope Science Institute. Lost And Found: Hubble Finds Much Of The Universe's Missing

Hydrogen. Posted 5/4/2000. Retrieved May 4, 2000, from the World Wide Web, http://oposite.stsci.edu/pubinfo/pr/2000/18/pr.html.
[56] One form of galaxy competition has actually been given the technical name of "galaxy harassment." Jack O. Burns. Stormy Weather in Galaxy Clusters. *Science*, Volume 280, Number 5362,17 Apr 1998: 400 - 404
[57] Stephen Battersby (1998). Galactic structure: The music of the spirals. Nature 394, 6 August 1998: 524; James Glanz. From a Turbulent Maelstrom, Order. *Science* 1998 April 24; 280: 519;

[58] Jarrod R. Hurley, Michael M. Shara. The Promiscuous Nature of Stars in Clusters. The Astrophysical Journal, Volume 570, Issue 1, May 2002:. 184-189.
[59] K. Bekki. Duncan A. Forbes, M. A. Beasley, W. J. Couch, Globular cluster formation from gravitational tidal effects of merging and interacting galaxies. Monthly Notices of the Royal Astronomical Society, June 2002.
[60] S. N. Shore, An Introduction of Astrophysical Hydrodynamics (Academic Press, San Diego, CA, 1992; P. J. E. Peebles, Principles of Physical Cosmology (Princeton Univ. Press, Princeton, NJ, 1993); Guinevere Kauffmann, Frank van der Bosch. The Life Cycle Of Galaxies. *Scientific American*, June 2002, Vol. 286 Issue 6: 46-56. Retrieved August 30, 2018, from the World Wide Web
http://ehostvgw7.epnet.com/ehost.asp?key=204.179.122.140_8000_-838197652&site=ehost&return=n&custid=nypl&IP=yes&profile=web&defaultdb=aph.
Retrieved August 30, 2018, from the World Wide Web
http://ehostvgw7.epnet.com/ehost.asp?key=204.179.122.140_8000_-838197652&site=ehost&return=n&custid=nypl&IP=yes&profile=web&defaultdb=aph.
[61] M. Ledlow, in The Second Stromlo Symposium: The Nature of Elliptical Galaxies, M. Arnaboldi, G. S. Da Costa, P. Saha, Eds. (ASP, San Francisco, 1997), vol. 116, p. 421; James Binney. The evolution of our galaxy. Sky & Telescope (ISSN 0037-6604), March 1995, vol. 89, no. 3, p. 20-26; Gary A. Mamon. Theory of Galaxy Dynamics in Clusters and Groups. Dynamics of Galaxies: from the Early Universe to the Present, 15th IAP meeting held in Paris, France, July 9-13, 1999, Eds.: Francoise Combes, Gary A. Mamon, and Vassilis Charmandaris. ASP Conference Series, Vol. 197, 2000, p. 377; A.E. Evrard, T. Horikawa, Virgo Consortium Collaboration. Precise Calibration of the Virial Theorem from Hubble Volume Cluster Catalogs. American Astronomical Society, HEAD meeting #32, #18.04, 10/2000.
[62] Lee Smolin. 1997. The Life of the Cosmos. New York: Oxford University Press.

[63] One galaxy cluster alone is in the range of 200,000,000 light years across. "Cosmos" Encyclopædia Britannica <http://www.britannica.com/eb/article?eu=117757>
[64] Jack O. Burns. Stormy Weather in Galaxy Clusters. *Science*, Volume 280, Number 5362,17 Apr 1998: 400 – 404; University Of Massachusetts At Amherst. New Map Of The "Nearby" Universe Reveals Large-Scale Structure Of Galaxies. Reprinted from ScienceDaily Magazine. Retrieved June 7, 2001 from the World Wide Web http://www.sciencedaily.com/print/2001/06/010606073512.htm.
[65] Science Volume 284, Number 5420 Issue of 4 Jun 1999, pp. 1609 - 1610 FLUID DYNAMICS: Soap Films Reveal Whirling Worlds of Turbulence Robert Irion.
[66] Sidney Perkowitz. "It's Bubbles All the Way Down:" The Science and Art of Foam. American Physical Society, Annual March Meeting, March 12 - 16, 2001 Washington State Convention Center Seattle, Washington Meeting ID: MAR01, abstract #A4.003. 03/2001; Sidney Perkowitz (2000). Universal Foam: from cappuccino to the cosmos. New York: Walker & Company. John Archibald Wheeler with Kenneth Ford (1998). Geons, Black Holes & Quantum Foam New York: Norton; Rien van de Weygaert. The Cosmic Foam and the Self-Similar Cluster Distribution. Large Scale Structure in the X-ray Universe, Proceedings of the 20-22 September 1999 Workshop, Santorini, Greece, eds. Plionis, M. & Georgantopoulos, I., Atlantisciences, Paris, France, 03/2000 p.135
[67] Adrian Melott. Cluster Correlations and Large-Scale Structure. American Physical Society, April Meeting, Jointly sponsored with the High Energy Astrophysics Division (HEAD) of the American Astronomical Society April 20-23, 2002 Albuquerque Convention Center Albuquerque, New Mexico, Publication Date: 04/2002.
[68] Photo from: "Cosmos" Encyclopædia Britannica <http://www.britannica.com/eb/article?eu=117757> [Accessed May 21, 2002]. For the story of how gravity parted the cosmic fog, see: James Glanz. Wending Through Time, a Cosmic Web Gives the Universe Structure. New York Times, August 14, 2001. Retrieved August 14, 2001, from the World Wide Web.
[69] C.-P. Ma. New Perspectives on Cosmological Structure Formation. American Astronomical Society Meeting 199, #147.01 Publication Date: 12/2001.
[70] Tooby and Cosmides express a common misconception in their statement that: "Natural selection is the only component of the evolutionary process that can introduce complex functional organization in to a species' phenotype" Stuart Kauffman looks at the creative nature

of this cosmos a bit more realistically: "Since Darwin we have come to believe that selection is the sole source of order in biology. Organisms, we have come to believe, are tinkered together contraptions, ad hoc marriages of design principles, chance, and necessity. I think this view is inadequate. Darwin did not know the power of self-organization. Indeed, we hardly glimpse that power ourselves. Such self-organization, from the origin of life to its coherent dynamics, must play an essential role in this history of life...we must rethink evolutionary theory. The natural history of life is some form of marriage between self-organization and selection." Cosmides, L. & Tooby, J. (1997). Evolutionary Psychology: A Primer. Santa Barbara: Center for Evolutionary Psychology, University of California. Retrieved June 1999 from the World Wide Web: http://www.clark.net/pub/ogas/evolution/EVPSYCH_primer.htm; Stuart Kauffman. "What is life?: was Schrodinger right?" in Michael P. Murphy and Luke A.J. O'Neill, editors. What is Life? The Next Fifty Years: Speculations on the Future of biology. Cambridge: Cambridge University Press, 1995: 111.

[71] Hideyuki Kamaya, Joseph Silk (2002). On the possibility of observing H_2 emission from primordial molecular cloud kernels. *Monthly Notices of the Royal Astronomical Society*, Volume 332, Issue 1, pp. 251-256. May, 2002.

[72] Hazel Muir. New record for Universe's most distant object. NewScientist.com, March 02, 2001. Retrieved August 30, 2018, from the World Wide Web http://www.newscientist.com/news/print.jsp?id=ns99992046

[73] Kenneth M. Lanzetta, Noriaki Yahata, Sebastian Pascarelle, Hsiao-Wen Chen, Alberto Fernández-Soto. The Star Formation Rate Intensity Distribution Function: Implications for the Cosmic Star Formation Rate History of the Universe. *The Astrophysical Journal*, 05/2002. Space Telescope Science Institute. Stellar "Fireworks Finale" Came First In The Young Universe. Reprinted from ScienceDaily Magazine. Retrieved August 30, 2018, from the World Wide Web.

[74] C. Jones and W. Forman, in Clusters and Superclusters of Galaxies, A. Fabian, Ed. (Kluwer, Dordrecht, Netherlands, 1992), pp. 49-70.

[75] J. Jaaniste, E. Tago, M. Einasto, J. Einasto, H. Andernach, V. Mueller. The supercluster-void network. IV. The shape and orientation of superclusters Astronomy & Astrophysics, August 1998, volume 336: 35-43.

[76] NASA/Marshall Space Flight Center. Black Holes In Distant Galaxies Point To Wild Youth, Chandra Discovers. Reprinted from ScienceDaily Magazine. Date Posted: Wednesday, June 05, 2002. Retrieved August 30, 2018, from the World Wide Web http://www.sciencedaily.com/releases/2002/06/020605072709.htm

[77] Charles Bennett. The Life and Death of Stars. Cosmology 101. NASA's Microwave Anisotropy Probe. Retrieved August 30, 2018, from the World Wide Web http://map.gsfc.nasa.gov/m_uni/uni_101stars.html.

[78] Henry A. Kobulnicky. The Impact of Massive Starbursts on the Chemical Evolution of Galaxies. Thesis (PHD). University Of Minnesota , Source DAI-B 58/08, p. 4277, Feb 1998. Retrieved August 30, 2018, from the World Wide Web http://adsabs.harvard.edu/cgi-bin/nph-abs_connect. C. Sneden. Early Galactic Nucleosynthesis of the Heaviest Elements. American Astronomical Society Meeting 199, #41.02 Publication Date: 12/2001 Kristin Balder-Froid. Glenn Seaborg's Greatest Hits. Lawrence Berkeley National Laboratory. Retrieved August 30, 2018, from the World Wide Web http://teidnt3.lbl.gov/seaborg/hits.htm. S. Rosswoga, C. Freiburghaus and F.-K. Thielemann. Nucleosynthesis calculations for the ejecta of neutron star Coalescences. Nuclear Physics A, Vol. 688 (1-2) (2001) pp. 344-348. Dartmouth College. Astronomers Find Carbon Monoxide Gas In Supernova Debris. Dartmouth News, January 1999. Retrieved August 30, 2018, from the World Wide Web http://www.dartmouth.edu/pages/news/releases/jan99/nova.html. Ron Cowen. Gamma-ray bursts reveal distant galaxies. Science News, April 28, 2001; Vol. 159, No. 17. Retrieved August 30, 2018, from the World Wide Web http://www.sciencenews.org/20010428/note9.asp

[79] Retrieved August 30, 2018, from the World Wide Web http://www.webelements.com/webelements/elements/text/Ra/key.html http://www.webelements.com/

[80] I've given two figures for the numbers of protons in this paper. The first, 10^{88}, is the number of protons spat out in the first fury of the Big Bang. The second figure, 10^{77}, is the number left after a vast mass of protons had met their antiproton counterparts and disappeared.

[81] Lucy M. Ziurys. Evolution of the chemistry in dense clouds. IN: The evolution of the interstellar medium; Proceedings of the Conference, Berkeley, CA, June 21-23, 1989 (A91-55426 24-90). Astronomical Society of the Pacific, San Francisco, CA., 1990: 229-246. Aake Nordlund. Star Formation Gamma-Ray Bursts Project. Niels Bohr Institute for Astronomy and Physics, University of Copenhagen. Posted September 30, 2001. Retrieved August 30, 2018, from the World Wide Web http://www.astro.ku.dk/~aake/snf/proposal/text.html.

[82] 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.

[83] 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, p. 23-51. Retrieved August 30, 2018, from the World Wide Web http://adsabs.harvard.edu/cgi-bin/nph-abs_connect.
[84] David F. Blake, Peter Jenniskens. The Ice Of Life. *Scientific American*, August 2001, Vol. 285 Issue 2, p 44-50.
[85] Francois Raulin. Prebiotic chemistry in the solar system. In ESA, Formation of Stars and Planets, and the Evolution of the Solar System p 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.
[86] 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.)
[87] 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
[88] L. Novotny, M.R. Beversluis, K.S. Youngworth, T.G. Brown. Longitudinal Field Modes Probed by Single Molecules. Physical Review Letters, June 2001, vol. 86, Issue 23, pp. 5251-5254 Retrieved August 30, 2018, from the World Wide Web.

http://adsabs.harvard.edu/cgi-bin/nph-bib_query?bibcode=2001PhRvL..86.5251N&db_key=PHY&high=3ce5646fdb08770; Researchers Find The "North Pole" Of The Molecular World. University Of Rochester Date Posted: Friday, June 22, 2001. Reprinted from ScienceDaily Magazine. Retrieved fro the World Wide Web June 22, 2001 http://www.sciencedaily.com/releases/2001/06/010605075137.htm
[89] Alan Saghatelian, Yohei Yokobayashi, Kathy Soltani & M. Reza Ghadiri. A chiroselective peptide replicator. 15 February 2001 Nature 409, 797 – 801. Retrieved August 30, 2018, from the World Wide Web http://www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v409/n6822/full/409797a0_fs.html. New Study By Scripps Scientists Sheds Light On Key Step For Origin Of Life. Scripps Research Institute, La Jolla, CA. Date Posted: Friday, March 2, 2001. Reprinted from ScienceDaily Magazine. Retrieved March 2, 2001, from the World Wide Web http://www.sciencedaily.com/releases/2001/02/010220072030.htm.
[90] Richard A. Kerr. Early Life Thrived Despite Earthly Travails. Science 1999 June 25; 284: 2111-2113.
[91] J. 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 30, 2018, from the World Wide Web http://adsabs.harvard.edu/cgi-bin/nph-abs_connect
[92] J. William Schopf, Anatoliy B. Kudryavtsev, David G. Agresti, Thomas J. Wdowiak & Andrew D. Czaj. Laser–Raman imagery of Earth's earliest fossils. Nature 416, 07 March 2002: 73 – 76.; Jeff Hecht. Tiny fossils may be Earth's oldest life. NewScientist.com. Retrieved August 30, 2018, from the World Wide Web http://www.newscientist.com/news/print.jsp?id=ns99992001
[93] Wendy K. Johnston, Peter J. Unrau, Michael S. Lawrence, Margaret E. Glasner, and David P. Bartel. RNA-Catalyzed RNA Polymerization: Accurate and General RNA-Templated Primer Extension. Science 2001 May 18; 292: 1319-1325. Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/content/full/292/5520/1319?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&author1=Johnston%2C+W.&fulltext=RNA&searchid=1023912961259_2147&stored_search=&FIRSTINDEX=0&fdate=4/1/2001&tdate=6/30/2001; Study Offers Insights Into Evolutionary Origins Of Life. Whitehead Institute For Biomedical Research. Date Posted: Friday, May 18, 2001. Reprinted from ScienceDaily Magazine. Retrieved May 18, 2001, from the World Wide Web

http://www.sciencedaily.com/releases/2001/05/010518083259.htm
[94] Elizabeth Pennisi. Direct Descendants From an RNA World. Science Volume 280, Number 5364 Issue of 1 May 1998, p 673.
[95] Richard J. Mural, Mark D. Adams, Eugene W. Myers, et. al. A Comparison of Whole-Genome Shotgun-Derived Mouse Chromosome 16 and the Human Genome. Science 20 December 2001; accepted 29 April 2002 10.1126/science.1069193 Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/content/full/296/5573/1661?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&searchid=1023915231580_2574&stored_search=&FIRSTINDEX=0&volume=296&firstpage=1661&fdate=1/1/1995&tdate=12/31/2002; Oscar Aurelio, David H. Hall, and Oliver Hobert. Immunoglobulin-Domain Proteins Required for Maintenance of Ventral Nerve Cord Organization. Science 2002 January 25; 295: 686-690. Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/content/full/295/5555/686?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&author1=Hobert&fulltext=PVT+%2BZIG&searchid=1023915946011_2728&stored_search=&FIRSTINDEX=0&fdate=10/1/1995&tdate=6/30/2002
[96] J. Craig Venter, Mark D. Adams, Eugene W. Myers, et. al. The Sequence of the Human Genome. Science, Volume 291, Number 5507, Issue of 16 Feb 2001, pp. 1304-1351.Retrieved August 30, 2018, from the World Wide Web http://www.sciencemag.org/cgi/content/full/291/5507/1304?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&fulltext=yeast+%2Bhuman+%2Bdna&searchid=1023916246329_2788&stored_search=&FIRSTINDEX=0&fdate=10/1/1995&tdate=6/30/2002
[97] For one hint to the question of whether fission and fusion are empty similes or Evolutionarily Stable Strategies, try this: "Some of the evidence ...shows that living things, including the human brain, tend to 'dwell' in metastable coordinated states poised near instability where they can switch flexibly. They live near criticality where they can anticipate the future and not simply react to the present. All this involves 'new' physics of self-organization, in which, incidentally, no single level is any more, or less, fundamental than any other." (J.A. Scott Kelso and Hermann Haken. "New Laws to be expected in the organism: synergetics of brain and behaviour." In Michael P. Murphy and Luke A.J. O'Neill, editors. *What is Life? The Next Fifty Years: Speculations on the Future of biology*. Cambridge: Cambridge University Press, 1995: 156-157.)
[98] Retrieved August 30, 2018, from the World Wide Web
http://www.atomicarchive.com/Fission/Fission1.shtml
Software and Multimedia Atomic Archive
AJ Software & Multimedia
[99] Artist rendering of the Battle of Bunker Hill
Retrieved August 30, 2018, from the World Wide Web
http://www.usatoday.com/life/travel/leisure/gallery/boston/freedomhill.jpg

USA Today Travel & Leisure Gallery, Boston.
[100] Retrieved August 30, 2018, from the World Wide Web http://www.exzooberance.com/virtual%20zoo/they%20walk/chimpanzee/chimpanzee.htm
exZOOberance, Overland Park, KS
[101] "ROSAT position-sensitive proportional counter x-ray contours of the Coma cluster overlaid onto an optical image from the Palomar Observatory Digital Sky Survey." Science Volume 280, Number 5362 Issue of 17 Apr 1998, pp. 400 - 404 Stormy Weather in Galaxy Clusters Jack O. Burns.