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Book Reviews

This Issue of the Journal of Big History is

Dedicated to

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1938 - 2017

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Published Works

Big History, Small World: From the Big Bang to You. Great Barrington, MA: Berkshire Publishing Group, 2016.

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Imagining the Unimaginable: Narratives of the Big Bang Time, Space, Matter, Energy

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Abstract: The term big bang has an uneasy history of problematic and misleading implications. As a derogatory and simplistic metaphor it is incompatible with current understandings of Planck time, inflationary theory, self-organizing dynamics, and emergent complexity. Scientific theory is judged and accepted as much by vocabulary as by content; content-specific nomenclature is a crucial key to understanding. Additionally, imaginative nomenclature that triggers a narrative meets the human need for a relevant story. Creative descriptions for the big bang that reformat it as a complementary cluster of stories are herein proposed with acronyms appropriate to the action of the big bang and meanings consistent with current science; approaches through analytical physics and complex mathematics are here replaced with series of suggestive narratives. Together, they combine to create a multi-strand narrative compatible with our present understanding of cosmic history understood as the Grand Sequence or the Big Story. Additionally the acronyms central to this presentation emphasize that the foundations of reality as we know it—Time, Space, Matter, and Energy—did not exist before the big bang but were in fact created in that event.

Anyone venturing into astronomy or cosmology inevitably has to grapple with the big bang. While there are more complex topics in science—quantum physics, for instance, or cell signaling—big bang cosmology challenges our customary experience and understanding of the world. It is simply impossible to imagine how an entire universe could unfold from next to nothing or how time and space—the apparent containers of everything we know—could have come into existence rather than always existing. Lawrence Krauss (2012) makes "a universe from nothing" seem simple, logical, and inevitable; most of us find it otherwise. The following notes provide a brief history of the big bang idea, its eventual acceptance, and current understandings organized into some unique ways to historicize or narrativize what we might more congenially call the big beginning or the first event.

History of the Term Big Bang

Marshall McLuhan, noted for his aphoristic analyses of communication, often said that to label is to libel. The term big bang, coined in a radio broadcast in 1949 by astronomer Fred Hoyle, provides an apt illustration: his off-the-cuff invention of the term was dismissive and derisive. "In the 1950s," Steven Weinberg has said, "the study of the early universe was widely regarded as not the sort of thing to which a respectable scientist would devote his time" (1977, 4), to which Alan Guth has added, "neither he [Hoyle] nor anyone else would use such a silly phrase [as "big bang"] in a dignified scientific publication" (1997, 99).

In the early twentieth century, the prevailing cosmology favored an eternal universe which seemed to fit contemporary understanding of the laws of physics, though a universe with no beginning is as conceptually difficult as one with a definite beginning. The replacement theory originated with observations in the 1920s that suggested the Universe may have had a beginning and thus a history. It began with Edwin Hubble's discovery that galaxies were retreating at varying velocities and calculations that distant galaxies were moving faster in a systematic fashion. Tracking them backwards in time suggested a common origin, though Hubble (1929) thought it "premature to discuss in detail the obvious consequences of the present results" (Bartusiak, 423-424). George Lemaitre (1931), however, felt no hesitation in putting forth the idea that the whole universe had been produced by the disintegration of a "primeval atom" (Bartusiak, 324). Arthur Eddington (1931) recognized the consistent and inescapable logic of an expanding universe with a distinct beginning in time, but resisted it: "Philosophically the notion of a beginning of the present order of Nature is repugnant to me. I should like to find a genuine loophole" (Bartusiak, 450). Preferring a steady-state, eternal Universe, Eddington argued that "the most satisfactory theory would be one which made the beginning not too unaesthetically abrupt. . . . There is no hurry for anything to begin to happen" (1932,56). This reticence continued for several decades. When George Gamow cautiously opened up his discussion of the creation of the universe, he avoided the term big bang, preferring instead to speak of "the great expansion" following an "originally homogenous primordial material" (1952, 4), implying a dramatic but quiet beginning. Even in his discussions of Hoyle's opposing concept of an eternal, steady-state universe, Gamow declined to dignify the big bang by even mentioning Hoyle's dismissive invention of the term. Resistance took many forms. Until his death in 2001, Hoyle maintained his opposition to the idea of a universe with a beginning despite the accumulating evidence in the latter half of the twentieth century.

Acceptance of this idea was delayed until the 1960s when evidence for the theory of the big bang began to accumulate. The first evidence arrived somewhat by accident in 1965. Two scientists working for Bell Laboratories in New Jersey were attempting to eliminate background noise in newly designed radio antennae. Arno Penzias and Robert Wilson were skilled technicians, not astrophysicists; thus, when they discovered that "noise" was arriving wherever they pointed their antennae, they decided consultation was in order. While the signal was exceedingly weak, its arrival from every point in the universe added up to a colossal amount of energy. When scientists from Princeton looked over their telescope, rechecked every aspect of its design, and were unable to eliminate this persistent noise, they concluded they were hearing something that had been predicted—if the big bang had actually occurred: leftover radiation emanating from every part of the universe, red shifted beyond the visible spectrum.

By the early 1980s, following this telltale evidence of what is now called the cosmic background radiation (CBR), the libelous intent of the term big bang had virtually disappeared: Weinberg (1977) had outlined "the first three minutes" of the universe with impressive mathematical support, Joseph Silk had published *The Big Bang* (1980), and Alan Guth (1981) had introduced his clarifying theory of super-inflation occurring during a few trillionths of the first second. Notably, all three provided descriptions and analyses that far surpassed the limited connotations of Hoyle's "big bang." Since then, the term has continued to gain traction through various analyses and retellings (Trefil 1983; Gribbin 1986; Smoot 1993; Singh 2004).

Even after the event of the big bang had become accepted by the scientific community, the term itself remained bothersome, implying the universe began with an explosion. In an e-mail to this writer (11 November 2011) astronomer Eric Chaisson of Harvard University noted that he refers to "the t = 0 event" while Steven Weinberg tends to speak of "primordial chaos." In the 1980s Carl Sagan initiated lunchtime discussions at Harvard to find a better name and even ran a contest in his class, but struck out, while Alan Guth and Joseph Silk use "big bang" without apology. In the 1990s, Timothy Ferris, then editor of *Sky and Telescope*, called the big bang "a misleading, ugly and trivializing name." Accordingly, he announced a renaming contest that drew 13,099 entries—few from cosmologists, many from punsters, creative humor abounding—with judges Carl Sagan, Hugh Downs, and Ferris himself. The results announced in the February 1994 issue found none achieving what Sagan called the "felicity" of big bang. As Eric Chaisson has summarized the issue, Occam's razor seems to apply; big bang is simple, efficient, and dramatic or, as Simon Singh puts it, "short, punchy and memorable" (2004, 483).

The big bang metaphor, however, diminishes what quantum physics, mathematical reconstruction, and computer simulation indicate occurred at the inception of the universe, which is too easily visualized as a bursting balloon at a child's birthday party, or the detonation of a bomb. Supernova and kilonova explosions, recently observed in real time (Soderberg 2008; Cho 2017) continue to reinforce this version of events. Undoubtedly, explosion imagery is partly responsible for discomfort with and rejection of the entire idea. A communication challenge remains: undoing misconceptions inherent in the term and developing more accurate descriptions. The big bang is now understood as a complex event bracketed between timelessness and history, between nothingness and, eons later, an estimated 350 billion galaxies arranged in filaments across hundreds of millions of light years, a cosmology vast and unimaginable. Given the limiting features of all language, illustrative metaphors and narratives should harmonize with this new cosmology.

As humans situated within a limited space-time matrix, we are naturally led to an idea of the big bang as occurring within Newtonian space and time. As such, the term implies an event in a material medium located in space at a point in time. Logically, however, there was no physical or temporal framework yet available; all attempts to locate this event require a space-time framework that unfolded later. Thus, in comparison with other uses of metaphor in astrophysics—white dwarfs, black holes, or dark energy—the big-bang metaphor distorts and evades the uniqueness of what we now believe happened.

A term such as big beginning (BB) is a close variant of big bang that entails fewer conceptual hazards but, while less problematic, it provides little more than an alternate name for a temporal (t) point: Chaisson's $t = 0$ event. As an event with meaning for the present human situation, however, the big beginning must necessarily be imagined in narrative form, a first episode in what Chaisson (2006) calls the "epic of evolution," for narrative, as Donald Brown (1991) puts it, is a "human universal" such that young children and humans from every culture exhibit narrative understanding as a fundamental cognitive endowment. While early accounts of the big bang by Joseph Silk (1977) and Nigel Calder (1983) included elements of narrative, they also included minute dissections of the first microseconds into "eras" (Planck, Inflationary, Hadronic, Leptonic, and Decoupling), introducing a complex chronology mathematically precise but seemingly irrelevant and excessively detailed for anyone outside a very limited specialty. From the standpoint of quantum physics, such microscopic periodization may be mathematically precise and thus necessary, but ordinary learners, who make up more than 99% of the population, will prefer and in fact require some kind of meaningful narrative of how everything began, especially because "everything" includes their world, their possessions, their families and friends, and their own minds and bodies. Pure objectivity is a necessary ideal of scientific investigation and description, but relevance to self is the emotionally necessary foundation of interest and attention.

Assuming "big beginning" as a non-contentious synonym for big bang, the task of communication must be redefined: How can this incomprehensible event when time began, space unfolded, matter appeared, and energy bifurcated into various forces be formulated as imaginative narratives that will broaden and deepen its meaning and significance in harmony with discoveries over the past half century? How can we revision it in an interesting fashion, avoiding the complex physics which is best left for scientists, and capture the overall story? The following mini-narratives conveniently capture and summarize big-bang narratives this has writer has developed for a core-curriculum course that includes Cosmos, Earth, Life, Humanity, and Culture—a history of the universe formulated in a framework friendly to the humanities: Cosmic Narratives (Wood 2011; 2016). In literary terms, narratives can be as extended as Gustave Flaubert's three-hundred-page *Madame Bovary* or as brief as a simple declarative summary: "Romantic fantasies destroyed Emma Bovary." News anchors regularly introduce the news hour with a series of brief sentences that will be expanded to stories of several minutes later in the broadcast. Here we are looking for succinct summary narratives of the big bang that are capable of expansion into a detailed and comprehensive story. For interest, we have looked for stories that could be summarized in acronyms. Our current understanding of the big bang includes the creation, not simply of the Universe, but the underlying structures of reality—Time and Space, Matter, and Energy—which are necessary for our existence. To link the story of the big bang to these underlying structures, we have imaginatively used TIME, SPACE, MATTER and ENERGY as acronyms. This presentation should not be regarded as a conceptual change, new science, or alternative history but rather as imaginative ways of recasting science and history for a new view of the origin of things.

The Initial Moment of Emergence (TIME)

Without change, there is no way to measure time. Our present understanding indicates that there was no change before the event of the big beginning and therefore no time; the big bang marks the beginning of change and time. An expanded version of the big beginning, The Initial Moment of Emergence (TIME), signifies the beginning of temporality as we know it along with the concept of emergence basic to cosmic history. TIME thus provides a useful summary that is pedagogically useful: once it is introduced it tends to stick. I find students adopting it in written work in place of the traditional term "big bang."

In thinking about the beginning of the universe (or the world), we tend to wonder when it occurred, "it" being a particular datable point on a vast linear time scale. As Dalrymple (1991), Gorst (2001), and Montgomery (2012) have documented, numerous Medieval scholars made attempts to provide a date for the beginning of the world based on a literal reading of genealogies in the Bible, the only ancient source that appeared to cover the entire history of the world. Such historical constructions derived from an ancient book (*biblios*) might be called bibliotemporality. The second-century theologian, Theophilus of Antioch, provided the first, but at least 125 dates were calculated over the centuries. Eventually Bishop James Ussher's date of 4004 BC published in *Annals of the World* (1649) won acceptance, largely because of his close association with the British monarchy and thus the Church of England; his dates were printed in the margins of the King James Bible well into the twentieth century. Bibliotemporality has now been superseded by radiometric dating which has reset the beginning of the world at 4.5 billion years ago. Moreover, observations of a systematically expanding universe, the predicted discovery of the cosmic background radiation (CBR), and recent detection of vast gravity waves in the CBR have established and verified a cosmology in which the beginning of the universe itself is placed 9.3 billion years earlier—13.8 billion years ago. Despite an inconsequential minority of dissenters, big-bang cosmology has won the day throughout the scientific community.

It must be admitted, however, that the big bang label is imaginatively and cognitively limited. It implies a massive explosion with flying debris in all directions. We are overloaded with explosions in movies, on the battlefield, and in increasing acts of terrorism, but explosions are destructive events whereas The Initial Moment of Emergence was a creative event; it provided the impetus for the formation of an immense collection of galaxies and planets that followed, and for the eventual rise of life that occurred on at least one planet billions of years later. In order to link the big beginning with the present universe, we need a narrative that unfolds its temporal stages (epochs, or eras). Additionally, we need essential punctuation pauses within the temporal narrative, for time, as Einstein theorized and science has since verified, is subject to velocity: hence the "atemporality" of light and other radiation recognized by Julius Thomas Fraser (1982) that preserves and delivers a record of all earlier times to the present. Other punctuation points include the "petrotemporality" of rocks and meteors that preserves past "times" of the 4.5-billion year history of Earth, and the "genotemporality" that records landmarks in the history of life within the human genome (Wood 2015b).

As a simple alternative for the big beginning, The Initial Moment of Emergence (TIME) provides a framework for such a narrative: it implies and confirms a basic assumption that an initializing event occurred at t = 0, before which no time existed, and follows this with a temporally organized process of emergence. All narratives begin with change occurring because of an initial disequilibrium, followed by a sequential ordering of events (Sacks1964; Bal 1985), a narrative pattern that gratifies a basic human need to understand causation (Abbott 2008, 41)—how and why things happened the way they did. TIME defines a change in time: emergence is a temporal process of "rising out" (Latin: *e-mergere*), a coming forth of something formerly hidden, and in fact is now seen as basic to modern cosmology—a process repeated through what Fred Spier (1996) calls the "domains" of cosmic, planetary, and human history. Mario Bunge (2003, 12) provides a succinct definition: "Wholes possess properties that their parts lack. Such global properties are said to be emergent." Emergence associated with new thresholds of complexity occurs throughout cosmic history; a 13.8-billion-year sequence of emergences is traceable through particulate, stellar, chemical, biological, anthropological, and cultural development, thus casting all of cosmic history as evolutionary—a series of emergences associated with new layers of tiered complexity.

Emergence as the narrative thread of evolutionary and human history has been recognized over several decades by Norman Berrill (1955), Alan Broms (1961), John Pfeiffer (1969, 1977), Charles Maisels (1990), and Steven Johnson (2001); additionally, Mark Bedau and Paul Humphreys (2008) have gathered perspectives from more than twenty philosophers and scientists. Emergence is thus one of the most intensively studied aspects of cosmic history, perhaps because it is quietly recognized as a replacement for the millennia-old mythology of supernatural design as the organizing principle of the material Universe. Emergence describes the appearance of four forces from a single undifferentiated energy and the subsequent emergence of quarks that make up the various particles of elemental matter. Emergence captures the appearance of new properties in each of the elements fused from hydrogen in stellar furnaces, supernova, and kilonova explosions. At the chemical level, emergence describes the appearance of new properties when elements are combined to create millions of familiar compounds and, later, the achievement of reproductive capacity when complex arrangements of chemical molecules form living cells. Laboratory scientists seem reticent to dwell on these rather astonishing results of emergence, perhaps apprehensive that theology or mysticism may make inroads into science. But we should note that emergence even at the level of the material world is a mysterious process; in fact, the astonishing capacity for creativity in the material world has periodically given rise to connotations of spirituality, as in the work of Edmund Sinnott (1955), Pierre Teilhard de Chardin (1959), and Ursula Goodenough (1998). However, emergence remains a neutrally safe concept implying an appearance of innovation and complexity without prior causation. Emergence is also central to human organization as we witness the innovation and creativity emerging from social and cultural complexity and remarkable social applications emerging from the mechanical complexity of computers and the Internet. The Initial Moment of Emergence gives birth to Time, the thread upon which all subsequent emergences and complexities are strung in the Grand Sequence of cosmic history.

Single Point Achieving Cosmic Extension (SPACE)

Two spatial descriptions of the big beginning emphasize cosmic history as narrative: Single Point Achieving Cosmic Extension, and Singularity Potential Activating Cosmic Expansion (SPACE). Both add additional plot strands in the unfolding narrative following TIME. The former, focusing on the word "achieving," emphasizes a final spatial result; the latter, utilizing the word "activating," links tidily with the "initial moment" of TIME. Both introduce connotations at the boundaries of imagination, but explanation makes them cognitively accessible. "Achieving" and "activating" imply change in time and thus distinctive narratives. According to our present understanding, no spatial extension existed before TIME. "Single point" and "cosmic extension" provide a dramatic contrast between an infinitesimal, metaphorical "space" at $t = 0$ and the nearly infinite expanse of real space eventually achieved; the visible universe now measures 26 billion light years in diameter, though its full extent is much greater. "Singularity potential" and "cosmic expansion" focus attention on a different aspect of origins and effects. Activation began at a point, though not a point "in" space understood as a container of things and events; rather, this event occurred at all points or, conversely, all points began as one point prior to the unfolding of space. Indirectly, the notion of "one point prior to the unfolding of space" sets aside the imaginative difficulties that virtually everyone puzzles over: How big is space? Where does it end? What lies beyond the end of space? All such questions are unanswerable because they are framed within a Newtonian space which did not yet exist. The creation of space by expansion renders old questions obsolete and makes tenable the logic of "a universe from nothing" described by Lawrence Krauss (2012). The initial point from which all points in space emerged, understood as devoid of physical dimension or position, is termed a singularity, although it encompasses the capacity for infinite multiplicity. An additional emphasis of this acronym is the introduction of expansion as now understood, and its corollary, inflation, part of big-bang theory ever since Guth (1981) proposed it and now apparently verified by polarization within the CBR. SPACE describes the initial event in terms of extension—not the expansion of matter "into" space but as the expansion of space itself between galaxies and galactic clusters, a recognition that requires the theory of dark energy to account for observations otherwise unexplainable. The value of SPACE is its incorporation of concepts on the leading edge of our present scientific understanding.

Matrix Acting Toward Titanic Exothermic Radiation (MATTER)

With the introduction of a third acronym, we begin to sense the depths of creativity implied in the big beginning as we now understand it. Matrix Acting Toward Titanic Exothermic Radiation (MATTER) carries a rich set of narrative connotations. Archaically, matrix refers to the womb, a meaning tracing to the Latin *mater* (mother) and numerous cognates in Indo-European languages. Additionally, matrix provides a context where properties yet to emerge are implicit, folded in (*im-plicatus*) until they become explicit, or unfolded. In modern usage, a matrix encloses while ultimately imparting an emergent form or shape that develops and evolves with unwrapping (*de-volupere*) or turning outwards (*e-volvere*). The result is a titanic rush of energy, heat, and radiation akin to the torrential rain of a typhoon. Titanic derives from the Titans of Greek mythology, a race of giants who, among other cosmic disruptions, raised Chronos (time) and Typhon (storms) to rule the Universe—analogous perhaps to contrasting forces of order and entropy.

The radiation component of MATTER actually precedes matter as we know it, referring to a limited period following the big beginning of approximately 300 to 400 thousand years when the initial undifferentiated plasma was so dense, entangled, and constrained that radiation could not escape, thus rendering it invisible today. This constraint is explained by quantum physics: energy is packaged as discreet quanta, which for a few hundred thousand years were packed too densely to escape. But energy as discrete quanta underlies many features of the universe scientists have now discovered: the exchangeability of matter and energy, the regular succession of atomic mass in the chemical elements, consistent spectrographic signatures for elements and compounds, and measurable isotopic decay utilized in radiometric dating. "Exothermic radiation" describes the torrential outpouring of heat attending the earliest minutes following the event describe as TIME and SPACE. As a possible alternative for titanic, torrential is equally connotative since its Latinate meaning is scorching or boiling (*torrens*).

While MATTER refers to this limited era when the material universe emerged, the unspoken connotations of the acronym suggest a far broader narrative encompassing the entire material universe as we know it today that has descended and evolved from the exothermic radiation from the initial event.

Entropic Nexus Emitting Radiation, Galaxies, and You (ENERGY)

A fourth narrative for the big beginning may be summarized as Entropic Nexus Emitting Radiation, Galaxies, and You (ENERGY), a formulation that carries the narrative far beyond radiation, the final chapter implied by the R of MATTER. In its inclusion of both entropy and you, this phrasing defines divergent cosmic trends: the paradox of a universe tending toward both disorder in its initial dispersal of energy and localized order and pattern described as "sensitive chaos" by Theodor Schwenk (1965). Subsequently, order has been explored in tandem with complexity emerging from multi-level self-organizing dynamics formulated by Erich Jantsch (1980), Ilya Prigogine (1984), Stuart Kauffman (1995), and Philip Ball (1999). At one extreme, the second law of thermodynamics governs a dissipating universe where accelerating expansion seems to foreshadow an irrecoverable scattering of matter and energy at some distant point, perhaps 100 billion years in the future. The earliest sign of an entropic universe was detected when the Cosmic Background Explorer (COBE) recorded the cosmic background radiation (CBR)—a nearly uniform mist of pure radiation later measured by the Wilkinson Microwave Anisotropy Probe (WMAP) at less than three degrees above absolute zero with variations across the entire universe of no more than a few thousandths of a degree. If we had no knowledge of subsequent cosmic history with the CBR as our only clue, we might conclude that the vast creative energy of an expanding universe had been utterly lost to the implacable power of entropy within 400,000 years after TIME.

The first observational proof of order emerging within a larger entropic context appeared when telescopes were focused on middle distances a billion or two light years after TIME. Here miniscule variations in temperature corresponding to equally miniscule variations in density in the CBR were recognized as forerunners of galaxies and chains of clustered galaxies spread like jeweled filaments across vast regions of space. Utilizing the enormous power of the Hubble Telescope combined with microlensing, we have extended our view back in time more than 13 billion light years, discovering billions of stars clustered in fledgling galaxies within half a billion years after the big beginning. Our own Milky Way and most other galaxies appear to have formed early in the history of the universe, 10 to 13 billion years ago. Since then they have continued to draw in matter from their own region with larger galaxies occasionally swallowing smaller ones that venture too close. In general, though, galaxies are the longest-persisting entities in the universe, except for atoms. Their longevity makes them the most significant entity emerging from the original cloud of elemental dust to their status as host for our own existence. Galactic organization is minimal—limited to the fine balance between the momentum of orbiting stars, an enormous amount of invisible dark matter, and the universal force of gravity that keeps hundreds of billions to a trillion stars together. The energy of momentum and the force of gravity working together maintain the order of galaxies as continuous with and emerging from the original nexus of matter-and-energy.

While many of the earliest galaxies were globular with little evident order beyond clustering, the most evolved galaxies have attained the visible symmetry of a vast flattened disc. As non-entropic concentrations of matter and energy, galaxies play host to stellar nurseries and billions of stars. The organization and structure of galaxies is relevant once we consider the range and variety of stars they engender. A galaxy provides a variety of stellar environments, from the frantic chaos of inner regions to the quieter realms of far flung galactic arms. In the inner regions stars orbit the galactic center at enormous speeds; their orbits are random, with interference and collisions more likely. In the outer regions of the large disc-shaped galaxies, stars run in roughly parallel paths, thus providing undisturbed stability that may last for billions of years. Stellar nurseries are evident through most galaxies but those of importance for higher levels organization occur in the central to outer regions of galaxies where the new stars that emerge have time and space to evolve more complex kinds of order.

The mathematics of stellar evolution is complex (Harpaz 1994; McWilliam 2004) but the story is simple (Gribbin 2000; Chown 2001), and it is a story that leads to humans and other life that may inhabit the universe as its final chapter. Any star significantly larger than the sun is subject to an enormous gravitational load; increasing density and rising temperature at its core turn it into a cosmic furnace that cooks the most basic element, hydrogen, into the next twenty-five. These and a score of others above iron on the Periodic Table are created and scattered through space during violent supernovas, and our most recent observations suggest that the upper forty or so, including gold, platinum, and uranium are fused in collisions of neutron stars (Cho 2017; Bloom 2017); these are perhaps a thousand times more violent and thus are known as kilonovas (*kilo*: thousand). The array of ninety-two sequentially constructed elements found in supernovae and kilonovae debris signals the emergence of complex chemical order from apparent chaos. Subsequently, within select regions near second-, third-, or fourth-generation stars, an additional reversal of entropy occurs—a counter tendency where higher elements provide material for new compounds, with some acting as catalysts in the creative complexity of the rest. Left-over debris from star formation accretes to form a variety of planets, some rocky that become pockets of stability where, in at least one instance, matter and constant energy flow gave rise to progressive forms of emergent complexity: life—self-replicating entities populating every ecological niche of the planet. In time, the fundamental sensitivity of such entities led to millions of species, aggregate communities, culture, thought, and imagination. ENERGY captures this force of counter-entropy in its description of an "entropic nexus emitting radiation, galaxies, and you."

The inclusion of You shifts the emphasis of TIME, SPACE and MATTER in a radically new direction, which is unapologetically subjective; indeed, anthropocentric. More than half a century ago, the

Canadian microbiologist Norman Berrill wrote a book called *You and the Universe* (1958). Published a year after the now-famous paper, "Synthesis of the Elements in the Stars" (Burbidge et al 1957), Berrill's presentation made clear for the first time that cosmic history unfolds as a continuous narrative from stardust (hydrogen, carbon, nitrogen, and oxygen, etc.) to the complex cells of which we humans are made. The universe displays multitudinous histories and entities, some of which— brown dwarfs, trilobites, dinosaurs, Neanderthals—have ended with extinction, but life has bifurcated into 300 million separate species, ninety-nine percent of which are now extinct. The three million alive today represent no more than one percent of all that have ever lived—though this number is still too great for any biologist to understand. But Berrill was interested in the specific pathway that provides a cosmic genealogy for humanity. Subsequent writers—Preston Cloud (1978), Joel Primack (2006), Cynthia Stokes Brown (2007), Brian Swimme (2011), and John Hands (2017)—have restated his theme with varying creative emphases. Tyler Volk (2017) has introduced the term "combogenesis" to describe the new foundation for a creative beginning that occurs with each successive emergence—"from quarks to culture"—that he calls the "grand sequence." An interesting narrative innovation has the Universe telling its own story (Darling 1989), the first of a trend towards an autobiographical history of life on Earth (Ridley 2000; Dawkins 2004); here cosmic evolution is cast in a framework of biological memoir. We live within what Brian Swimme called "the universe story" (1992) and Gianluca Bocchi termed "the narrative universe" (2002).

As synthesizers of scientific ideas, some contemporary writers have sought to make advanced science of our time accessible for the non-scientific reader by providing narrative bridges between the "two cultures" (Snow 1960), the sciences and the humanities (Wood 2013). Carl Sagan (1980) achieved early visibility and brought cosmology out of the shadows; Neil de Grasse Tyson (2004) has achieved similar success. Jennifer Morgan (2002, 2003, 2006) has created a beautifully illustrated, three-volume version of the universe story for children. Expanding on the idea of "cosmic education" outlined by Mario Montessori (1976),Michael and D'Neil Duffy (2014) have articulated five "great stories" for the elementary classroom. A sequence of "big story narratives" (Wood, 2015a) for elementary and middle school children provides an alternate methodology. The presentation of the big beginning as a narrative of energy transformation that links its earliest events with our present human situation is perhaps the most potent way for cosmic history to achieve meaning and significance outside the specialized domains of science.

The appeal of reformatting the big beginning as TIME, SPACE, MATTER and ENERGY is both practical and pedagogical, an exercise in imaginative story making. Big History teachers who are not scientists tend to slide past the big bang, which is only fully understood by science specialists. Historians treat the history of civilization at length. Biologists emphasize evolution; geologists focus on the forces of plate tectonics and orogeny. But the big bang should not remain out of reach, an arcane arena of quantum physics. Properly understood, it is seen as laying down the foundation for everything that follows. College and university teachers bear responsibility for communicating the most advanced concepts from the sciences in terms not only comprehensible but also meaningful for the next generation. An analysis of the first microseconds into a series of fleeting "eras" registers the analytic power of advanced mathematics and quantum physics, but it loses traction for students whose primary interest lies in the humanities—or even for students in other branches of science. Given the fundamental allure of a meaningful story, the big beginning requires narrative connectivity with Earth, life, and the human situation. Above all, it needs imaginative presentation.

The goal of the International Big History Association (IBHA) is to unify scientific knowledge in a grand framework defined as an "attempt to understand, in a unified, interdisciplinary way, the history of Cosmos, Earth, Life, and Humanity" (Christian 2011, 20). Norman Berrill (1958) and Preston Cloud (1978) produced impressive cosmic histories, though too early to include the opening big-bang chapter; more recent studies by David Christian (2004), Cynthia Stokes Brown (2007), Brian Swimme (2013), and Walter Alvarez (2017)—all prominent big historians—necessarily include it, though, as the title of this article implies, thinking about the big bang is always a matter of imagining the unimaginable. Tyler Volk (2017) has made the big-bang pre-atomic story of quarks as understandable as it may ever become for the non-scientist. Our series of narratives summarized as TIME, SPACE, MATTER, and ENERGY are not intended as scientific contributions but rather accessible literary versions of the big beginning—an opening chapter and an evolutionary story that Darwin never dreamed of. At the same time, these acronyms double as the fundamental realities upon which the Grand Sequence of cosmic history has been written. Edward O. Wilson (1998) captured this sequence in the phrase "epic of evolution"; Eric Chaisson (2006) developed it into a narrative of seven ages; Cheryl Genet (2009) has assembled the conference proceedings of more than thirty scholars exploring "the evolutionary epic." Narrative as a fundamental method for presenting cosmology has earned a unique place straddling the sciences and humanities. This expansion of the human past—from history to big history—was first defended by David Christian (1991); it has gained acceptance in the new millennium, not only with the 2010 formation of IBHA but also affiliates in Europe and Asia. In the inaugural volume from the Santa Fe Institute dedicated to complexity science, David Krakauer et al (2017) have undertaken a sweeping examination of big-history theoretical foundations with essays from a wide range of scientists and social scientists. The Big History emphasis on the narrative continuity of cosmic history links every later development in the universe to the big beginning. The unity of space and time as worked out by Albert Einstein has gradually gained clarity. The interchangeability of matter and energy is less obvious; we tend to regard rocks, trees, insects, and people as made of different "stuff." Yet the material and movement of our bodies—every molecule of brain and bone, every heartbeat, every thought flickering across the cortex—derives from the history of the universe, tracing back through numerous energy transformations to exfoliating radiation when everything began.

New descriptions for the big bang or the big beginning, with its most recent emergent identified as you, emphasize the significance of humanity as the most complex product of the 13.8-billion-year history of the Universe. We may soon detect signs of life in nearby exoplanets, but confirmation that it has achieved complexity equal or greater than ours will require technological sophistication and communication that may lie decades or centuries in the future. For now, the miniscule 200-thousand-year history of *Homo sapiens* remains the final chapter in the narrative. In this light, it is appropriate to explore and reinvent our presentation of the big bang in order to set aside lingering misconceptions, explore its multiple story lines, and bring into focus the profound importance of this event as the departure point for a scientifically-based narrative leading to our own recent emergence.

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Evolution of the Early Solar System in Terms of Big History and Universal Evolution

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Abstract

The present contribution is devoted to some aspects of history and evolution of the early Solar system. The origin of the Sun, Earth, other planets and its satellites has long been a matter of great concern for people. Over the past few decades astronomers and cosmologists have considerably advanced in the perception of the structure, history, and evolution of the Solar System. However, one can hardly speak about a proper narrative here; we more often work with hypotheses. The present paper is structured as follows. First, it outlines the history of formation of the Solar system in the first hundred million years of its existence, when the most considerable changes took place. Then while describing certain formative processes we show the opportunities to define them in terms of evolutionary laws and rules. Of course, this paper presents only a few such laws and rules. We suppose that the present study will be of interest to a reader in two ways. First, there are quite a few consistent and brief surveys of the Solar System history accounting for the latest achievements in astrophysics and cosmology. Meanwhile, they are very important and productive for theorizing part of Big History. Second, the discussion employing the general evolutionary laws and rules allows defining some common features in the formation of the Solar system and especially of its planetary system which are characteristic for every level and stage of Big History. This brings us to the idea of the integrity of Big History not only in historical and systemic terms but also with respect to its integrity in detecting general laws, patterns and mechanisms.

Keywords: Solar system, exoplanets, protonebula, dust subdisk, planetesimals, planet embryos, protoplanets, catastrophes, planetary migration, rules and laws of evolution, trigger, struggle for resources, primary systems.

Introduction

The present contribution is devoted to some aspects of history and evolution of the early Solar system, that is to the first billion years of its existence. This period is crucial for understanding how and why the Solar system has become what we know it. One should point that there are many hypotheses and theories about the formation of planets of the Solar system. Still none of them can explain the whole range of related issues.

This paper is a continuation of my previous work (Grinin 2014) both in the sense of the period and in methodological terms. In my former paper (Ibid.) I considered the key events of the cosmic phase of Big History starting from its Star-Galaxy Era, which I described in terms of universal evolutionary principles. In the present paper I will investigate the evolution and history of the early Solar system and against this background I am going to show the possibility to define a number of events of this history in terms of evolutionary laws and rules.

This approach has been deliberately chosen since it allows amplifying the Big History methodology with the achievements and principles from Evolutionistics. As I wrote elsewhere, although Big History provides unique opportunities to consider the development of the Universe as a single process, one should point that Big History studies tend to pay little attention to such an important aspect as the unity of principles, laws, and mechanisms of evolution at all its levels. I believe that combining the Big History's potential with evolutionary approaches can open wider horizons in this respect. Indeed, the common traits in development, functioning, and interaction can be found in different processes and phenomena within Big History. In this respect the universal character of evolution is expressed in the objective similarities that are detected in many manifestations at all its levels. Such an approach opens new perspectives for our understanding of evolution and Big History with their driving forces, vectors, and trends, and for creating a consolidated field for a multidisciplinary research (Grinin 2014, 163–164). This approach also produces a synergistic effect revealing new aspects of our Universe and of the world's integrity.

From the evolutionary point of view I divide the early history of the Solar system into four great epochs.

The first epoch was the formation of protosun and protoplanetary disk from the solar nebula. This was the epoch of formation of 'order out of chaos' in Prigogine and Stengers's terms (1989) lasting for about a million years after the collapse of the protosun cloud.

The second epoch was the formation of solid matter, planet embryos and primary planets. It can be denoted as the epoch of struggle for resources – lasting for about 10–50 million years after the collapse.

The third epoch can be called the epoch of planet migrations and catastrophes – lasting about 600–700 million years about 3.9–3.8 billion years ago.

Finally, the Solar System's current architecture has been established.

The fourth epoch is the so-called Late Heavy Bombardment of the planets and their satellites by planetesimals and meteorites which lasted from 900 million to 3.2 billion years.

As has been mentioned above, the research into the Solar system evolution allowed revealing a significant number of processes and events that can be described in terms of general evolutionary laws and rules. In the present contribution I try to show that there are many similarities and common features manifested in the most different processes and phenomena at various stages and levels of Big History.

I suppose that this contribution will be of interest to the readers in two ways. First, there are quite a few consistent and yet brief surveys of the history of the Solar system accounting for the latest achievements in astrophysics and cosmology. Meanwhile, they are very important and productive for theorizing part of Big History. Second, the accompanying discussion employing the general evolutionary laws and rules allows us to reveal some patterns in the formation of the Solar system and especially of the planetary system which are common for different levels and stages of Big History. This brings us to the idea of the integrity of Big History not only in historical and systemic terms but also with respect to its integrity in detecting the general laws, patterns and mechanisms.

Due to the scope of the paper I have chosen the related evolutionary rules, laws and patterns only to some (and far not all) events of the early history of Solar system (for details see Grinin 2017a).

1. The formation of the protosolar system from a gas-dust cloud

With respect to the Solar system history there are still more hypotheses than proven facts. Yet, year by year the hypotheses concerning certain phenomena are supported by direct observations, for example, as a result of discovery of numerous exoplanets.

The age of the Solar system, determined with the radioactive dating technique from the study of the oldest meteorites is about 4.57 billion years (Shukolyukov and Lugmair 2003; Vityazev and Pecgernikova 2010, 168; Pfalzner et al. 2015). The major features of the system were formed during the first few hundred million years, but the actual narrative of this period is still extremely fragmentary and unreliable.

Over the past two or three decades, there has been elaborated a so-called standard scenario for the formation of a planetary system from a protoplanetary gas-dust disk surrounding a protostar, which allows defining the general outlines of the process.

Supported by numerous direct observations, the model of the birth of stars is generally used to reconstruct the origin of the protosun. The stars are usually formed in the densest parts of molecular gas-dust clouds, the latter composed mainly of hydrogen and helium and having a temperature approaching to absolute zero. The gas clouds can preserve equilibrium for many millions of years. There is needed a certain impulse (a trigger) to launch the condensation process (and subsequent collapse). Perhaps, for the birth of the Sun such a trigger may have been the shockwave from a nearby supernova about two million years before its collapse started (Adushkin et al. 2008, 276) .

Here we deal with a general evolutionary rule which I have defined as a rule of necessary triggering phenomena or events to launch evolutionary process. On the one hand, this can hardly work without internal readiness of a system; and, on the other hand, even a high-level internal readiness itself can hardly ensure the start of a transformation just as gunpowder cannot be exploded without fire. Without a trigger, a system can for a long time remain potentially ready for transformations and still no changes will occur.

The above-mentioned rule works at all evolutionary levels. For example, there is a well-grounded hypothesis on the role of the cooling that took place 6–8 million years ago and led to the formation of large open spaces in the East Africa. It promoted the evolution of Hominids named Dryopithecus living in trees into bipedal upright walking Hominids of the Australopithecus or another type (Kessler 2017; Niemitz 2010).

In social evolution the triggering phenomena would be necessary for the formation of an early state. In addition to increasing internal complexity of government and social stratification, a trigger is also needed in the form of an abrupt change in society. The latter may have been a war, an involuntary resettlement or opening of the given society to the outer world (as it happened to the Hawaiians in the end of the late 18th century with James Cook's discovery of the islands, see Grinin 2017b).

Along with condensation of the gas-dust cloud, there starts a contraction, or a free fall controlled by self-gravity, which, according to some assumptions, lasted for ten thousand years (Marove et al. 2008, 225; Motoyama Kazutaka and Tatsuo Yoshida 2003). The ongoing collapse makes the initial fragment of the nebula break into smaller clumps so that it usually can generate many stars. The continuing condensation within the clump makes its matter gradually concentrate thus preparing a transformation into a proto-star. The contraction is accompanied by heating while the structure of the future star is formed, including its core and shells. The center of the protostar gradually heats up.

After the outer and inner cores of the protosun had been formed, the rest of peripheral matter partially flew on the core and added to the mass of the forming star. This process of falling of matter (in the case of a protosun – of gas) onto the surface of a body is called an accretion. After the accretion shell falls essentially onto the protostar, the latter turns into a young star. Meanwhile, its inner temperature reaches several million degrees which launches thermo-nuclear reactions. The formation of the Sun as a star is supposed to take about a million years, but there are estimations prolonging or reducing this time span.

2. The formation of the protoplanetary bodies, planet embryos and protoplanets

The protoplanetary disk and its evolution. During the formation of a young star, a circumstellar disk is often formed visible across optical and shorter wavelengths. The leftover matter of the accretion disk is partially scattered into space as well as used in the formation of a pro-toplanetary disk. According to the observations, such disk around the stars exists from 5 to 25 million years.

The difficulty in the reconstruction of planetary formation process for the Solar System is compensated by a vast number of hypotheses and theories which have been developed over two centuries. But none of the hypotheses can explain the whole range of the facts related to the planets so far.

However, the vast majority of cosmologists believe that the Sun and planets were formed from a single cloud (protosolar nebula) whose matter differentiated into the Sun and the protoplanetary envelope, the latter evolving into a disk as a result of rotation. The rotation and fragmentation of this proto-planetary disk formed the planets in the course of a new cycle of accumulation of matter in protoplanetary bodies. Most cosmologists proceed from the idea that the planets were formed from cold material, which was later heated by shock wave, radioactivity and other processes. The formation of a protoplanetary disk is supposed to last from one to several million years. The mass of the protoplanetary disk is estimated between 3 and 10 % of the solar mass. Besides, it was spatially distributed and heterogeneous. The dimensions of the accretion disks of the young stars are 100–1000 astronomical units.

The disk was more heated in its inward parts while its external regions remained relatively cool. Some contractions occurred there, which contributed to the emergence of separate gravitational centers of planetary formation. Still the mechanism of this process itself was extremely controversial.

The formation of a dust subdisk. Apparently, the protoplanetary disk was composed of the gas from the protosolar cloud with molecular hydrogen and helium absolutely dominating (all other substances amounting for less than 1 %). Dust particles though accounting for 0.5 to 1.5 % of mass played a peculiar role. This dust was like microscopic solid particles (water ice, sticky molecules and atoms, in particular iron and other solid matter). As a result of the formation of the protosun which accumulated most part of gas, the dust concentration in the protoplanetary disk increased at the later stage of its evolution. But even more it began to increase as a result of the accretion of dust onto the middle plane of the disk.

Some cosmologists believe that the most probable way of formation of the planet embryos is through the accretion of dust particles onto the equatorial plane of the preplanetary disk (Zasov and Postnov 2011, 199). As a result, a dust-gas subdisk was formed in the center of the disk, but the "dust-gas" ratio in it already varied many times as compared with the surrounding space. The dust grains can also increase in size (due to sticking and pulling). Thus, the potential planetary system passed through a very important transition involving the concentration of solid matter (so far in the form of dust), which played an essential role in the growth of preplanetary bodies, and later planets. According to some models, the near-solar protoplanetary disk would evolve for one to two million years before a dust-enriched subdisk was formed.

Actually, the dust subdisk was comparatively thin and its thickness was by 103–104 times smaller than its radius. It had to be opaque to the sun rays, and therefore, they did not reach the periphery of the disk. Among other things this determined the varying conditions for the formation of planets, depending on the proximity to the protosun.

Here we deal with the general evolutionary rule of importance of heterogeneity and fluctuations. In this context dust can be considered as an element of heterogeneity in the clouds of molecular hydrogen. And the concentration of this solid matter launched the emergence of proto-planetary bodies, and later planets.

At all levels of Big History the evolutionary change requires the presence of critical heterogeneity which can trigger the regrouping of matter or elements in the assemblage. And a new structure and order arise on this basis. Meanwhile, an absolute homogeneity makes evolutionary processes impossible.

For example, a mutation can trigger speciation; whereas the groups of foreigners could play an important role in the transformation of many ethnic groups and early states.

The started formation of pre-planetary bodies. As some cosmologists suppose, for some time due to the gravity and turbulence the subdisk may have contracted while the dust and gas condensations and further clusters may have been formed within it. But the debating point is whether the planets have been formed from these dust and gas clumps (as the condensation theory maintains) or already from solid matter. The theory of formation of planets from solid matter is called the theory of successive accretion. Many, if not most cosmologists, consider it the most probable scenario. According to it, the tiny dust particles stick together, first forming small particles of solid matter, and then larger objects that gradually grew into planetary embryos. The particles of solid matter (from small to large kilometer or even thousand kilometer size) are called planetesimals.

The most important stage in the process of planetary embryos formation is the formation of large (entire) solid bodies-planetesimals. All theories and hypotheses agree on this point. However, with respect to the number, size and other dimensions of these large objects, there are considerable discrepancies. There are different estimations of the boundary size (critical for the process) planetesimals. The proponents of the theory of successive accretion of matter by planetesimals hypothetically consider the formation of millions and billions of kilometer-sized bodies, which gradually increase in the process of swarming. According to the condensation theory the largest objects could reach a thousand-kilometer size.

Among many forces that influenced the concentration and accumulation of matter, transformation of the proto-cloud matter into solid objects, determination of orbits and, in general, the protoplanetary formation, two forces are recognized to play a fundamental role in planet formation: gravity and solar radiation. And both of them directly depend on the distance of the object from the Sun. At the distance between 2 and 4 AU from the Sun, between the orbits of Mars and Jupiter, there is a theoretical boundary called an ice line, or a snow line. The ice line is the location where water has a transition from vapor to solid state since the intensity of solar radiation decreases with distance from stars. "At the location where the temperature is 160–170K so that water has a transition from vapor to solid state line itself, water molecules tend to accumulate as they boil off grains" (Lin 2008, 53). The ice line turns into an ice cluster which promotes creation of planetesimals.

Formation of large planetesimals. When the masses of planetesimals increase, their gravity allows them to attract closely-located particles. Thus, numerous kilometer-size planetesimals actively pick up primary dust. Their growth brought the emergence of the so-called protoplanetary planetesimal swarms. Gradually, there emerged a small-numbered 'elite' consisting of bodies of the size of the Moon or even Mercury. There are many hypotheses concerning the mechanisms of their generation as well as the number (from several to hundred ones). Over time, the orbits of the largest bodies became circular which made them the centers of attraction for surrounding matter thus becoming the planetary embryos. According to calculations, the formation of planetesimals lasted for tens and hundreds thousand years, while the formation of protoplanetary bodies from planetesimals took several million years.

Hypotheses about the growing planetesimals and the struggle for resources. The planetesimals would grow due to the accretion of matter, including gas, as well as to mutual attraction and accidental collisions. But the larger a planetesimal, the stronger is its gravity, and the more intensively it sweeps up its low-mass neighbors. When individual planetesimals' masses become comparable to the mass of the Moon, the gravity significantly increases so they can bounce off the surrounding bodies thus escaping collisions. As a result of struggle, clashes and merges, a small number of large cosmic bodies are formed, called the planetary embryos that dominate in their orbital zones and fight for the leftover matter.

At the same time, the growing planetesimals constantly collide and, sometimes merge or on the contrary, split after blows. The numerous splits allowed the larger bodies to capture more and more resources. The already large enough objects continued to grow. Gradually, the processes of self-organization began to prevail in this chaos.

Here we deal with the general evolutionary law of the struggle for resources and living space. The struggle for resources is a common mechanism of selection at all levels of evolution. The struggle for resources is an important constituent both of Darwin's struggle for existence in the biological world and of human economic competition. The advantages, including the accidental ones, play an important role at all levels of evolutionary selection . About the law of struggle for resources, see also below.

3. Formation of the protoplanetary system

Problems and hypotheses of the formation of planetary groups. Most researchers believe that the period prior to the formation of the first planets lasted for at least several million years. But the discrepancies in determining its duration are rather considerable depending on whether the researchers consider the formation of the Solar system planets as a simultaneous process or happening at different times. Yet, until quite recently the common idea has been that all planets were formed more or less at the same time. Today more scientists tend to believe that the planets emerged at different times, and the intervals between their formation could be up to millions and tens million years.

Thus, some scholars think that it was Jupiter that came first, then Saturn, and much later the terrestrial planets were formed (see, e.g., Lin 2008; Savchenko and Smaghin 2013; Christian 2004, 60 with reference to Taylor 2002, 59–60); still others believe that the Earth group planets emerged first (see, e.g., Marakushev et al. 2013; Vityazev et al. 1990). Some scholars think that at first the terrestrial planets were similar to the giant planets, but then they would lose their fluid envelopes (see, e.g., Marakushev and Zinovieva 2013; Yazev 2011, 357).

There is also an interesting idea that there has existed not one but two or even more generations of primary planets. There is an opinion that being not properly formed those primary planets would explode and become the asteroid belt. Still others think that Jupiter and Saturn may have pushed the primary planets into the Sun or "ejected" them from the Solar system. Thus, it took more than one attempt to form the current order of the planets in the Solar system.

Here we deal with the rule of the archaic character of primary systems. This refers to primary planets or stars as well as to primary biological species or say, to pristine states (about the latter see Grinin 2008). Systems are not formed mature and stable. They usually undergo several reconfigurations including the cycles of destruction and recreation. That is why the primary systems usually appear archaic while the superior systems would emerge as the secondary or tertiary and have more opportunities for self-regulation. Let us consider the first stars which emerged not later than 200–400 million years after the Big Bang (e.g., see European Commission 2011). It is accepted that the first stars were giant ones, much more massive than most of the later-formed stars (May et al. 2008). Due to the absence of carbon, oxygen and other elements that absorb energy from condensing clouds, the process proceeded more slowly in that epoch; thus, only giant clouds could condense to produce massive stars hundreds times larger than the Sun (Ibid.). Those giant stars lived only for a few million years (the larger is a star, the shorter is its life). Moreover, the first stars contained a small amount of heavy elements. Thus, more than one generation of stars could have changed until the amount of heavy elements gradually increased. The emergence of heavy elements from the 'dead-star stellar leftovers' resembles the formation of fertile soil from the remnants of dead plants. The circulation of matter in the Universe is always observed everywhere and at all levels (this is another evolutionary law, about which see Grinin 2013, 2014).

The causes of differences in formation models of terrestrial and giant planets. Since the planets of the Solar System are divided into two categories (terrestrial and gas giants), the problem of the difference of their formation patterns becomes essential. Was this formation fundamentally the same in both groups, while the differences were determined by the distance from the Sun, or was the process of formation of different groups of planets essentially different, or were there other combinations?

No doubts that the distance from the Sun defined the peculiarities of the planet formation models. Different orbital periods of planetary embryos (the farther the planet from the Sun, the longer the orbit) effected the opportunities to capture surrounding planetesimals and, respectively, the radius and mass of a protoplanet. The snow line effected a higher concentration of planetesimals and matter in certain regions of the Solar System which could also define the size of planets in different regions.

There are numerous hypotheses explaining the origin of the observed categories of planets. For example, there are arguments that gas giants were probably the first planets to form and take almost all gas, while the Earth-type planets got quite a few resources.

Here we again deal with the law of struggle for resources and note that the distribution of resources in the cosmic world is to the same extent unfair as in biological and social realms. For example, the struggle for resources that among stars and galaxies may proceed in the form of weakening of another object or its destruction (e.g., through a direct transfer of energy and matter from one body to another), in the form of 'incorporation', 'capturing', that is 'annexation' of stars and star clusters by larger groups. There are many cases of galactic coalescences. Thus, some astronomers maintain that throughout a few billions of years our galaxy has 'conquered, robbed, and submitted' hundreds of small galaxies, as there are some evident 'immigrants' within our galaxy, including the second brightest star in the northern sky, Arcturus (Gibson and Ibata 2007, 30). It is widely accepted that the emergence and expansion of a black hole may lead to the 'eating' of the matter of the nearby stars and galaxies. However, the 'eating capacity' of the black holes is greatly exaggerated in popular literature. In systems of double stars or in star-planet systems one may also observe such a form of interaction as the exchange of energy and resources (about cosmic struggle for resources see also Grinin 2013, Ch. 5).

Hypotheses and theories concerning the inner planets. There are three main approaches to the formation of terrestrial planets.

1) A planet's mass increases up to present size via accumulation of planetesimals (and meteorites) which results in a gradual separation of the planet's interior into core, mantle and crust (not in all the planets).

2) The formation of the terrestrial planets following the giant-planet pattern. However, later the terrestrial planets lost gases to space. Respectively, only their internal iron-nickel and silicate cores remained. Thus, the iron silicate nuclei of these protoplanet giants have turned into small independent planets. The stratification on iron nuclei and strong silicate shells prevented their explosive disintegration (Marakushev et al. 2013, 135–37).

3) The impact of Jupiter and Saturn on the formation of the terrestrial planets (see below).

Hypotheses and theories about the outer planets. The theory of planetary formation pays special attention to two giant gas planets which account for 92% of the mass of the whole planetary system (that is, Jupiter and Saturn, but especially Jupiter).

There are two major hypotheses describing the possible patterns of formation of Jupiter and Saturn composed mainly of hydrogen and helium. The first – contraction – hypothesis, explains the gaseous composition of the giant planets by the fact that massive gas-dust condensations – protoplanets – were formed within a massive protoplanetary disk, which later in the process of gravitational compression would transform into giant planets. However, this hypothesis does not explain why the composition of Jupiter and Saturn differs from that of the Sun as well as some other problems.

According to the second hypothesis of accretion, the formation of Jupiter and Saturn proceeded through two stages. At the first stage, solid bodies were accumulated similar to the processes with terrestrial planets, and after the mass of the largest bodies reached a critical value (of two to ten and more earth masses), the second stage would imply the accretion of gas onto these already quite massive bodies which took place on a time scale of 105–106 years. At the first stage, some gas from the Jupiter region dissipated so its composition would differ from the solar one, and this was even more evident in the formation of Saturn.

According to the competing contraction hypothesis, the temperature of the giant planets was also high at the early stage, but the dynamics of processes proved to be more reasonable within the accretion hypothesis. The formation of Uranus and Neptune, which contain less hydrogen and helium, is also better explained by the hypothesis of accretion, since most of the gas has already left the Solar System after reaching critical mass.

Still the process of the planet formation is rather slow due to accretion into nucleus. It may take several million years. Some researchers, in addition to the scenario of accretion into the nucleus, also consider that gravitational instability in dense and cool regions of the disk can lead to the formation of planets. The formation of planets due to gravitational instability may take much less time than it may require when they are formed via accretion on the core. There is also a hypothesis suggesting that gas giants are formed by a sudden collapse, leading to the destruction of the primary gas-dust cloud. But most cosmologists deny the possibility of gravitational collapse for planets because of their relatively small masses (recognizing it only for stars).

4. The planetary migration

As was previously thought, planets remain in the original orbits since their formation. But recently there has become popular the opinion that it took the planets about a billion years to occupy the current orbits. In its early history the Solar system was different, and it is quite probable that the outer Solar system was much more compact in size while the Kuiper belt was located closer to the Sun. There are many suggestions concerning the migrations of planets; yet, these are just hypotheses.

The change of the orbit of Jupiter and other planets. There are especially many suggestions concerning the migrations of Jupiter and Saturn. According to one of them, this gas giant must have formed within the inner part of the planetary system, near the snow line, when there was still a considerable amount of gas in the disk. So it had to move to its present orbit (Lin 2008). When Jupiter drifted to the Sun dragging Saturn, it functioned as a gravitational bulldozer, "pulling" several earth masses of ice matter into the system (Batygin et al. 2016). There is a hypothesis that about 600–700 million years after the formation of the Solar system Jupiter began drifting and came into orbital resonance with Saturn . The resonance changed the orbits of these planets since it slowed down their migration inside and sent them back to the outer part of the Solar System. The resonance greatly affected the whole Solar System. In particular, Neptune and Uranus exchanged the orbits since Uranus used to occupy a farther position from the Sun than Neptune (Ibid.; see also Batygin and Brown 2016).

It took some time for the planets to come out of resonance. Over a few million years the chaotic interaction between unstable giants "pushed" Jupiter inward to its present place, and other planets "moved away". Moreover, according to one of the exotic hypothesis in the course of such reconfiguration one of the giants may have been expelled to the interstellar space. Here we mean the hypothetic ninth planet which may have existed in the distant past.

Here we again deal with the rule of archaic character of primary systems according to which there are needed some large changes (maybe, even cycles of changes) before a system finds its balance.

In addition, the so-called late era of heavy bombardment, or, more precisely, a certain part of this epoch is probably associated with this resonance event (see Bottke et al. 2012, Gomes et al. 2005) . An immense amount of meteorite precipitation fell on rocky planets during this late period. Relatively recent studies have shown that this was a long era, which ended 3.2 billion years ago, that is, it lasted for almost a billion years.

Collisions and catastrophes in the early history of the Solar system. The most debated are the two supposed catastrophes that occurred during the first hundred million years. The first one was the collision of Venus with Mercury. Venus has a retrograde rotation (counter the rotation of the Sun around its axis) while most other large bodies in the Solar system rotate in the same direction with the Sun. Mercury has a non-proportional nickel-iron core, since its metallic core amounts to 60 or more percent of its total mass (Solomon 2003). There are several possible explanations here. One states this may be the result of a collision of Mercury with a large asteroid and as a result of this tangent blow Mercury has lost most of its mantle and shell (Yazev 2011, 48). There is also a more exotic alternative that Mercury was initially farther from the Sun and besides, it was not a planet but the satellite of Venus from which it later “escaped”. This explains both Mercury’s small size, more appropriate for a satellite, and the retrograde rotation of Venus. The mainstream theory here is the tidal effect of a large satellite (i.e. of Mercury) which long ago both retarded the planet’s orbital motion and even made it rotate in the retrograde direction (Ibid., 57–58).

Another famous hypothesis concerning catastrophes is the idea that between 30 and 100 million years after the formation of the Sun, a Mars-sized planet embryo collided with the proto-Earth and generated a huge amount of debris that later formed the Moon. This assumption has several alternatives. There exists a fascinating hypothesis that for millions years a protoplanet Theia may have orbited close to the proto-Earth and finally collided with it. The collision is thought to occur almost tangentially and at a relatively slow velocity. That is why some of the Earth’s and Theia’s mantles were ejected to the low earth orbit and from these debris the Moon was formed which started to rotate along circular orbit.

More hypotheses about collisions. We have mentioned above that about 600–700 million years after the collapse of the protosolar nebula Neptune migrated into a new orbit. Recently, a hypothesis has been put forward that there used to be not four but five giant planets in the Solar System, and that the fifth planet collided with migrating Neptune and pulled it to the current orbit while the fifth giant planet had collapsed into a cluster of debris which Neptune threw out into the Kuiper belt, that is, to the outskirts of the Solar System (Taylor Redd 2015; Nesvorný 2011).

Here we deal with a widely spread evolutionary pattern – the one of catastrophes. One can point that drama is characteristic of Big History in its every stage. In particular, a famous hypothesis states that the Cretaceous-Palaeogene extinction was caused by the asteroid impact at Yucatan about 65 million years ago (Harmon 2010). Moreover, catastrophes have considerably affected the course of social evolution as well. Let us give the example of the Black Death in fourteenth-century Europe. Catastrophes are one of the main mechanisms of selection at every Big History level. They may serve as triggers launching some processes, as well as destruct the flawed systems and expand the evolutionary opportunities for increasing variability.

About 3.8 billion of years the giants settled their current orbits. It is considered that after the establishment of the current order of planets and satellites there have been no considerable changes in the Solar system. Huge changes occurred with the planets themselves and in their geological structure, climate, atmosphere composition and other characteristics.

Conclusion

Now we can summarize the described above rules, laws, and patterns of evolution:

- the rule of necessity of triggering phenomena or events to launch the evolutionary process;
- the rule of important heterogeneity and fluctuations;
- the law of struggle for resources and living space;
- the rule of the archaic character of primary systems;
- catastrophes as an essential mechanism of selection.

But these are just a few evolutionary rules and laws. However, much of what we know about trends, patterns, and mechanisms which influenced the transformations within Big History as well as evolutionary laws, rules can be traced already in its cosmic phase. Sometimes in an inchoate and non-systemic form, or on the contrary, the most vivid manifestations may be found just in the cosmic phase. So when numerous characteristics and features typical for biological and social evolution (e.g., like the struggle for resources) are unexpectedly observed at earlier phases of Big History, one starts perceiving that the universal character of evolution is a reality with numerous manifestations.

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The Polyfurcation Century: Does the Evolution on Earth Have a Cosmological Relevance?

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Dedication: To the bright memory of my dear friend and colleague, Cynthia Brown, who helped me a lot in completing this paper.

Abstract

Special cross-disciplinary research and respective calculations done independently by scientists from various countries have shown that the 21st century is expected to be crucial for the human history. Current generations' activities will determine what exactly the turning point will look like and what direction the subsequent evolution will go. Modern physicists and specialists in heuristics are advancing strong reasons for the conclusion that there is no absolute ban on the range of purposeful mass-energy control and therefore, mind's cosmic-scale influence is potentially unlimited. Yet, the range of available intellectual self-control to escape destructive effects is under issue so far. How long can the technological power growth be reliably balanced by the advancing behavior-regulation qualities? From time immemorial, the relative sustainability of human communities (from primitive tribes to nations, social classes or world confessions) has been provided by the image of a common enemy. Inter-group conflicts have been abridging in-group violence and with it, have been setting the vector for the construction of life's meanings. Yet, the current level of technological development completed by blurring lines both between war and non-war technologies and between the conditions of peace and war has made this psychological inertia suicidal. So the problem of life's meanings is becoming the nucleus of the 21st century global problems: Will the human mind prove ready to develop strategic meanings beyond religious or quasi-religious ideologies which are always built on the "them-us" mental matrix? Insights of great philosophers and prophets, as well as special socio-psychological experiments and some crucial episodes in political history have demonstrated that besides the image of a common enemy, both human solidarity and strategic meanings can be built on the image of a common cause (not aimed at an enemy agent), although the experience of assimilating this kind of construct by the mass consciousness is scanty. Instead, historical evidence is abundant showing that after long periods without real or potential wars, life's meanings dilute and the masses feel nostalgia for new demons. Actually, we observe an intensification of this trend in many regions of our planet accompanied by a growing instability in global geopolitics. An international educational program designed to develop cosmopolitan worldviews free from group-versus-group attachments is suggested in the paper.

Keywords: prognostication, non-linearity, menace, danger, risk, singularity, scenarios, violence, techno-humanitarian balance, ideology, life's meaning.

In fact, the people living today are the most important ever to walk the surface of the planet, since they will determine whether we attain this goal or descend into chaos.
Mitio Kaku

The need is clear. The outcome is not.
Lowell Gustafson

To Start With: Comments on Methodology

Generals are always prepar .

Winston Churchill

In 2016, the Nobel Peace Institute held an international academic discussion on the mechanisms of violence, war and peace (see [1] and others). Most participants came to the conclusion that sharpening tensions in current political relations made a new world war inevitable in the 21st century. It is worth mentioning that the "world war" concept clearly reminded images from either the first or the second halves of the 20th century (which had been essentially different), and afterwards, in February 2017, the Swedish government re-introduced the army draft, which had been canceled seven years earlier.

This looks like the effect that sociologist Robert Merton called a self-fulfilling prophesy [2, p.477]. Later, an additional term self-NON-fulfilling prophesy emerged in the relevant literature. It implies that an opportune warning can help an escape from unfavorable developments or, inversely, an excessive confidence in one's coming success can interfere with the expected achievement. I will show, below, that the quality of projections and people's attitude to them has become a challenge to world civilization's destiny…

In December 2016, the Global Challenges Foundation in Stockholm invited me to write an analytical paper on the challenges that humanity faces in the 21st century. The invitation was willingly accepted, as my many years' experience in political psychology and system forecasting helps select points of importance in the continuing discussion. A journal version of the paper is offered here for readers.

Historical experience in social prognostication shows that the major cause of errors has been authors' propensity to linear extrapolations, which is consonant to hard determinism in classical science. Post-classic science has essentially changed attitudes to the concepts related to chance and nonlinearity and respectively, to the role of mental factors in the course of events. Modern methods are synthesized in synergetic (complexity theory) patterns, so far as they emphasize the instability phases and palliative scenarios and always mention the price for progress in any crisis solution; thus human thinking and will are involved in global causalities. Nevertheless, the scope of subjective influences is disputable, so that even though a model looks formally nonlinear (with exponential curves, etc.) the nonlinearity gradient, if underestimated, entails blunders.

The underestimated subsequent deflections from a linear model are in turn conditioned by two circumstances. First, by the short retrospective distance to be extrapolated, i.e. the most apparent current trend is transferred into an indefinite future. Second, by the insufficiently system oriented property of the analytic model: the extrapolation is inferred from separate fields like economy, power industry, demography, ecology and so on. This smoothes the "subjective" factors and causes inadequate appreciation of the actual opportunities and challenges. Meanwhile, comparative historical research shows that the specific weight of mental reality in the systemic causalities has been progressively growing and has achieved a very high magnitude.

"Challenge" in modern psychology of social security is a complex concept composed of three variables: menace, danger and risk [3]. Menace is any event that can damage the agent's interests. A living organism, even more a human individual or a society, permanently exist in the condition of outer and inner menaces which don't produce dramatic effects until the agent successfully copes with them. Danger is a more delicate variable: it is described as a relation of the menace to the agent's readiness to withstand it. Finally, risk is the probability of danger increasing in case of either certain activities or inaction.

Lowered menaces can provoke growing dangers in certain situations and vice-versa. A textbook example: whereas there are considerably more menaces outside one's place of residence, accidents and injuries (up to sudden deaths and killings) are more frequent at home. Having left the dwelling, one remembers about probable menaces, is more concentrated and ready to face them, while back at home, he/she relaxes and thus runs into unexpected troubles. Danger essentially increases in two cases: if one ignores, underestimates or neglects the menace and, on the contrary, if "the rabbit's attitude" entails the feeling of doom and one's own helplessness.

These definitions especially matter when we discuss the planetary outlook. With that, a predicting value essentially depends on how much the trends picked for extrapolation correspond to the prognostication scale and tasks. The actual historical situation is such that effective patterns of the future require a maximal retrospective distance and the systematic involvement of disciplinary fields from cosmology to psychology. This is now available in view of the fundamental scientific discoveries of the latest decades, which give us a new background to estimate the planet's observable futures.

Mega-History: A Cross-Disciplinary Research Project

...By now, this is the most complete knowledge about you and me,
about why we do exist and why we are so as we are,
about what might follow us and to what extent this depends on each one.
Yakiv Osvitleny

An empirical data array had been accumulated by the 1980s to argue

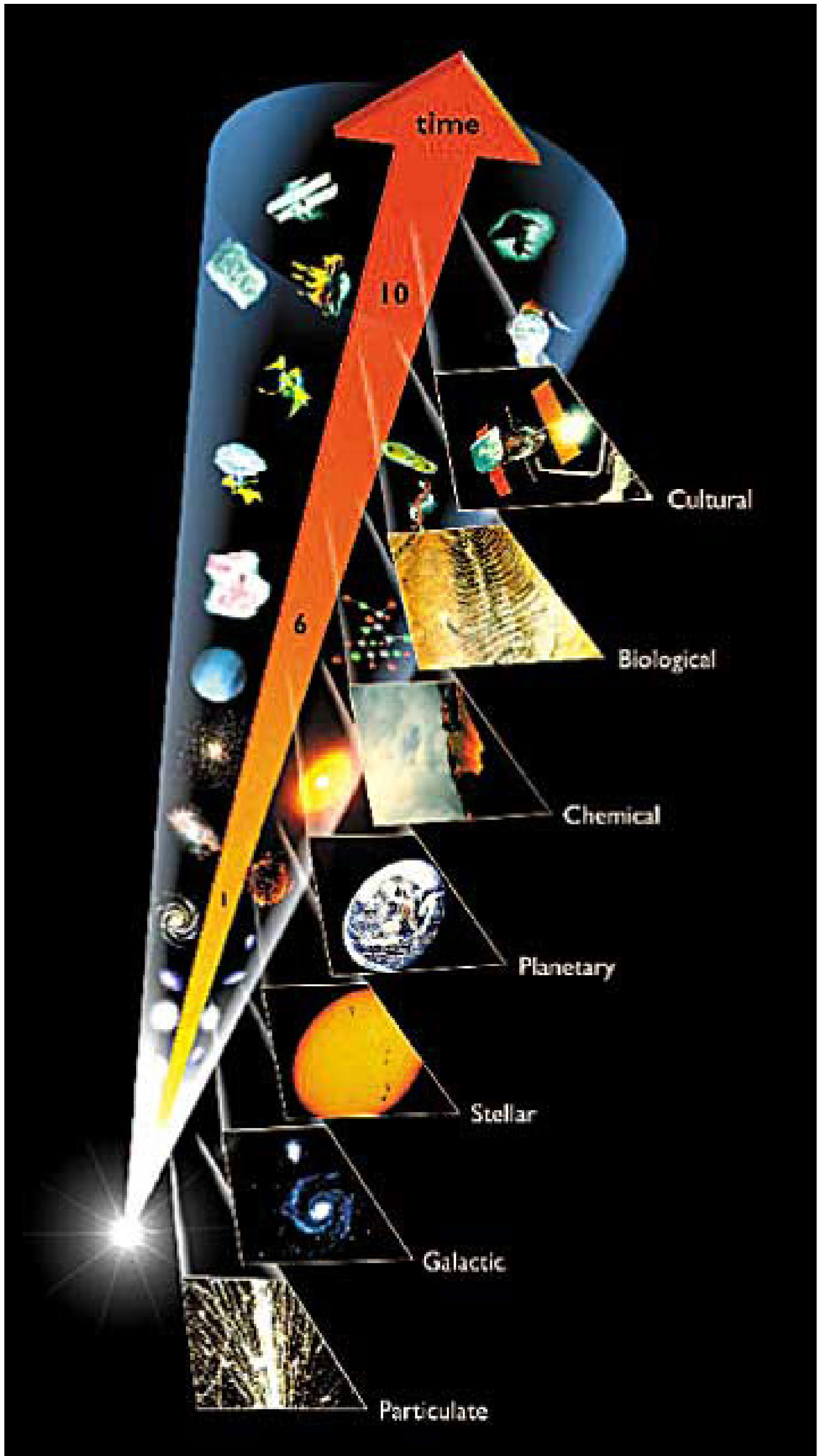

Fig. 1. The Stages of Cosmic Evolution (by Eric Chaisson)

that social history, prehistory and the histories of biosphere, Earth's crust and cosmos were a single process. We could distinctly trace back common vectors of the consecutive transformations over a period of almost 14 billion years, to the very horizon of actually available retrospection, the "Big Bang". The Metagalaxy has been successively evolving towards more and more complex and sustainable far-from-equilibrium conditions. Scientists from various countries and fields began to speak about a universal evolution, and a research project appeared aimed at an integrated image of the past, variously called Mega-History, Big history (see [3-13] and others).

The mega-trend of increasing complexity apparently contradicts the suggestions inferred from the classical natural history (time as growing entropy; heat death theory), but it is reliably corroborated by the empirical data in modern sciences and humanities; therefore, astrophysicists have to distinguish between the thermodynamic arrow of time and the cosmological arrow of time (see Fig.1) leaving under issue their causal relations.

The arrow looks rectilinear on Fig.1 yet the cumulative changes have not, in fact, been uniform. The first billions of years after the Big Bang, evolution had been slowing down until heavy elements were synthesized in the depths of first generation stars and ejected into the cosmic space by supernova explosions. This initiated an additional self-organization mechanism with competition for free energy (heavy elements unlike light ones need energy from outside). Thus about 10 billion years ago, as evolution went on its way towards organic molecules and living matter, the slowdown changed into acceleration: "the two hoses" of the universal evolution (see Fig.2).

The Solar system emerged nearly 4.6 billion years ago, and the first signs of living organisms on Earth are recorded since about 4 billion years ago. Recent discoveries in paleontology, biophysics and cosmology have reinforced the hypothesis of life's cosmic origin: the first organisms supposedly emerged somewhere in the Milky Way Galaxy, were carried by meteorites and nestled on all of the suitable planets during about 240 million years (one Galactic year). In particular, their first signs on Earth precede the appearance of the oceans [14, 15]. Some astrophysicists argue that highly intensive meteorite activity on the early stage of Solar System formation more than once brought primitive organisms to the Earth crust, but each time they were destroyed by the same bombing process. Life finally nestled only after the bombing had relatively reduced [16].

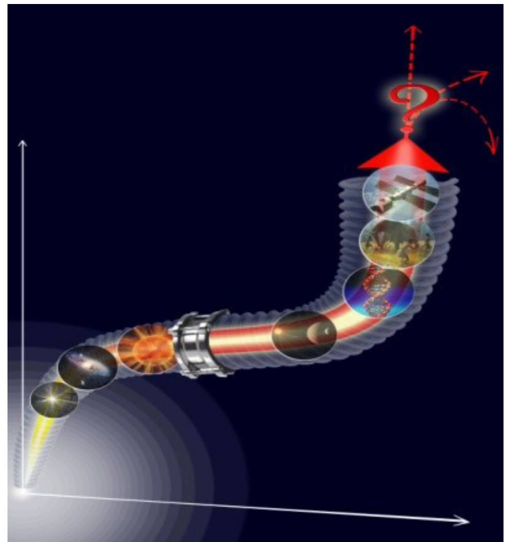

Fig.2. The two hoses of universal evolution (by Alex Pinkin, illustration to [3])

Anyhow, our planet was likely one of multiple points on which further cosmic evolution was localized. The important thing here is that the acceleration continued and followed an astonishingly regular regime. A series of independent calculations done by Australian, Russian and American scientists, who used different sources and even different mathematical instruments, show that the time periods between phase transitions in biospheric, pre-social and social evolution have been shortening in a simple logarithmic fashion for 4 billion years [15, 17-19] (see Fig.3).

These calculations disavowed the "exogenous" approach to explain the catastrophes and crucial episodes in both social and biospheric histories, in which analysts search for external causes like geologic, climatic or cosmic cataclysms, although this each time required artificial assumptions. In the

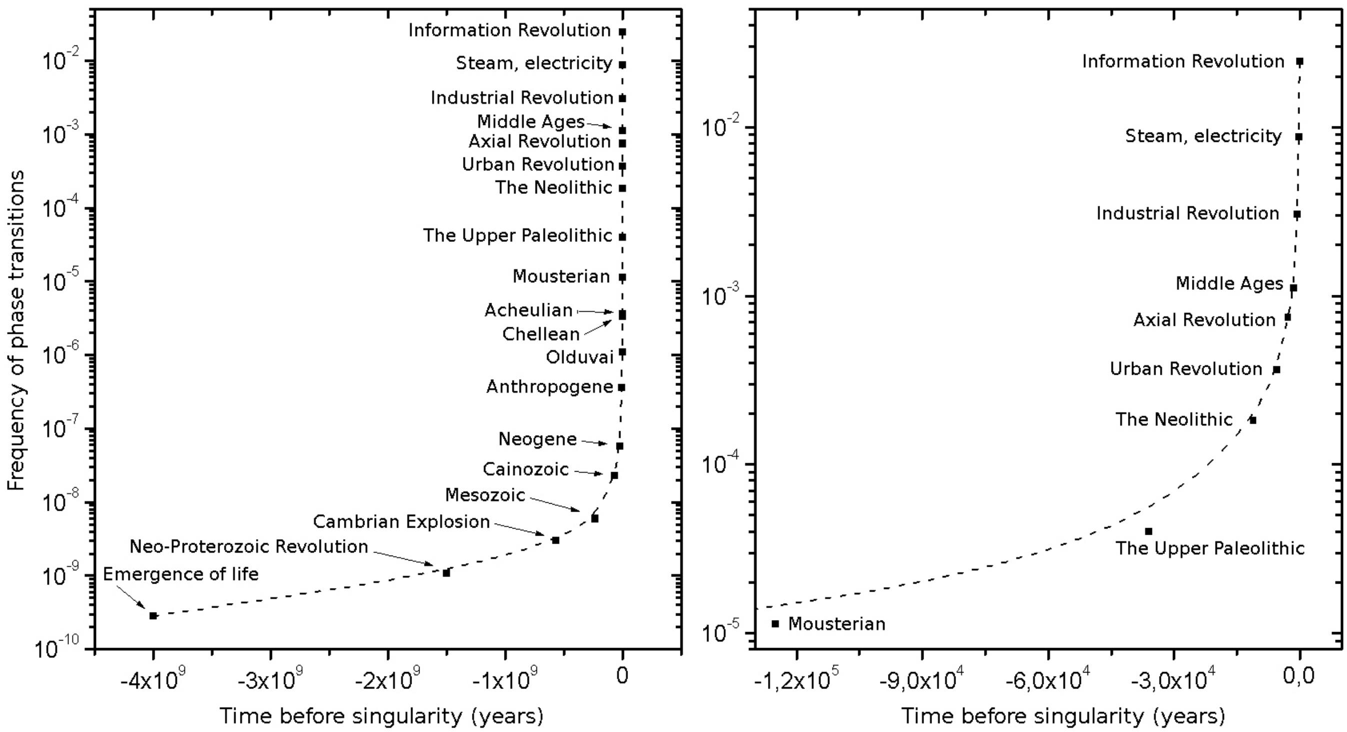

Fig.3. Scaling law in the phase transitions (by Alexander Panov [16]).

new version, the story looks different. Continents have been drifting, magnetic poles shifting, big meteorites falling down, powerful volcanoes erupting and climate repeatedly changing during the 4 billion years; later on, the wayward Homo sapiens intervened with their "free will" and never-ending extravagances, and about 10 thousand years ago (the Neolithic) the anthroposphere started to arise; nonetheless, the global transitions each time preceded by crises and catastrophes followed the logarithmic succession.

This paradoxical fact turns us to the synergetic pattern of delayed dysfunction [3]. The accumulation of negative effects of a sustainable non-equilibrium system's (biosphere and, later, society) anti-entropy activity entails, over time, environmental degradations which devalue the old mechanisms of sustainability and extensive development. Thus the outdated mechanisms provoke a catastrophic entropy growth, so that the system's subsequent viability requires more delicate mechanisms and advanced "intelligence". The global crises caused by the biosphere's or society's own activities have been each time solved by means of deep reconstructions and archaic subsystems' cutoff, like extinction of species and the destruction of social-natural entities.

Careful analysis of the crucial episodes shows that, over and over again, the events could have developed otherwise. The evolution of biosphere and later anthroposphere could have collapsed in a global catastrophe (the simple attractor, in synergetic terms) or have been suspended (the horizontal attractor) and slowly degraded with time. Yet, we live on this planet thanks to the fact that evolution has moved towards the vertical attractors in each turning point, that is, global sustainability has been each time reestablished by means of the explosive growth in the global system's complexity and its aggregate intellectual quality; this cost catastrophes of many separate subsystems, but it ensured new global sustainability on a higher and higher level of non-equilibrium. One more consideration originates from the General System Theory's implementation principle: all possible events do happen. From that, we must assume that alternative scenarios are performed in multiple points of the Universe and very few of the evolving planets achieve a level comparable to the one we find on Earth [3].

The Singularity Puzzle

The ever-accelerating progress of technology and changes in mode of human life… give an appearance of approaching some essential singularity in the history of the race beyond

could not continue.
John von Neumann

Having extrapolated the hyperbolic curve into the future, the researchers have come to a nearly unanimous (ignoring the individual interpretations) and even more striking result: around the mid 21st century, the hyperbole turns into a vertical. That is, the speed of the evolutionary processes tends to infinity, and the time intervals between new phase transitions vanish. The point on which the value of a function becomes infinite is called the singularity; therefore, the mentioned mathematical inference has been designated by the authors' names as Snooks – Panov's Vertical or Kurzweil's Singularity [20, 21].

The Mega-history inferences are corroborated by the calculations based on more particular parameters, like the accumulation of the genetic burden because of falling children's mortality and growing longevities, etc. Indeed, our civilization seems to be approaching at a growing rate the polyfurcation point whose planetary (and cosmic?) significance exceeds all the foregoing phase transitions. Thus, the four-billion-year-long evolution intrigue will be solved somehow or other during the current century. Cross-disciplinary investigations applying a synergetic pattern help discern three attractors beyond the mathematical Singularity, with a set of scenarios within each one.

1. Transition to history's "descending branch". European philosophers wrote a lot about this perspective in the 18th-19th centuries; yet they saw external reasons (like Earth aging or the Sun blowing out) and used to put this transition off many thousands, millions or hundreds of millions years in future. Now we see that the cause of history exhaustion can be exclusively humans' own activity and that the timetable amounts to decades. As we trace onward various anthroposphere and biosphere degradation scenarios we find that the process can continue from several days to millennia; anyhow, the simple attractor is that Earth will become a "normal" cosmic body like the Moon or Mars free from res cogitans and living matter at all.

2. Evolution's suspension guaranteed by a shift of core social activity to virtual reality – horizontal attractor. The "hang-up" may be long-term, but sooner or later, the escapist civilization will be absorbed by the growing universal entropy.

3. Transition from evolution's planetary phase to the cosmic one. This doesn't look idyllic either, since the cosmically relevant phase implies radical transformations in the mind's conditions, qualities and substrates (like man-machine structures and so on) as a premise for subsequent development: progress has never been the way "from the worse to the better" but just an alternative to the system's destruction.

Is a Cosmic Perspective Possible?

Probably, the "Silence of Cosmos" simply means that not a single planetary evolution has so far given birth to intelligence commensurate to its cosmic destination.
Vazgen Garun

Up to the end of the 20th century, most of respectable astrophysicists shared the belief that life, society, culture and mind were nothing but epiphenomena (side products) of material structures' blind game, without any potential influence on cosmic developments and doomed to dissolve in the ruthless universal entropy. The Nobel Prize winner, Steven Weinberg [22], expressed this common belief by noting that only the awareness of the unavoidable end imparts a color of a "high tragedy" to the "farce" of human existence. Moreover, according to the extreme version, what we call evolution is in fact an irreversible entropy growth in the Universe and humankind with its crazy ambitions is the "cosmic trash". Some Soviet astrophysicists or descendents from the USSR influenced by the "Russian Cosmic Philosophy" ventured to assume humans' potential intervention in the cosmic-scale processes and strategic perspectives; yet this was rather an exotic position in the 20th century science.

Following relevant papers from the late 1990s on, we can see that the conceptual mainstream has considerably changed. Abundant arguments for the assertion that consciousness is not a side product, but a "cosmologically fundamental fact" and it can conclusively influence subsequent evolution of the Metagalaxy, are widespread in recent astrophysical books and articles outside Russia (see [23-26] and others). The authors argue that no "physical laws" impose an absolute ban on creative engineering. Even before, studies in gestalt-psychology and heuristics had demonstrated that any boundaries were creatively surmountable by a change of the cognitive meta-system [27]. Specifically, those parameters of the problem situation that are uncontrollable constants inside a certain model become manageable variables within a more complex meta-model; this implies that both the range and scale of purposeful control of mass-energy flows are potentially unlimited.

Yet, if this is so, cosmos should be full of powerful civilizations! With up-to-date high tech, astronomers discover on average weekly a couple of new planets outside Solar system and several ones rather similar to Earth by their parameters have been lately found. However, all efforts to register a slightest intelligent activity sign remain fruitless. Thus the so-called Fermi Paradox ("Where are they?"), which was worded by the Italian physicist in the early 1950s (see in [28]) sounds more and more actual.

Technology, Psychology and Social Viability: The Law of Techno-Humanitarian Balance

We have created a Star Wars civilization, with Stone Age emotions, medieval institutions, and godlike technology.
Edward Wilson

To explain the paradox, the scientists referred to technical and conceptual troubles, but lately the "humanitarian" side has gotten growing attention. Summarizing diverse data from cultural anthropology, history, historical sociology and psychology concerning anthropogenic catastrophes, researchers have found a regular relation among three variables: technological potential, quality of cultural control (actual values and norms) and social sustainability: the law of techno-humanitarian balance. Namely, the higher is the power of production and war technologies, the more advanced behavior-regulation is required to enable self-preservation of the society [3, 21]. As soon as mind achieves power which is not compensated by adequate aggression-retention, it becomes destructive and in the short run, self-destructive for the society.

Each new technology (not only military) carries new menaces that entail catastrophes; their danger declines after social psychology and culture have adjusted to them. As special investigations show, many flourishing societies' tragic destiny was due to the unreadiness to cope with their own increased power, so that the natural or geopolitical backgrounds of their existence were subverted. History was continued by those who managed to balance their values and norms of activity with the new technologies within the proper time, and the selection of viable social organisms was intensified by global anthropogenic crises. The dramatic "scrapping" of imbalanced societies has entailed important positive consequences as well: while both the destructive power of technologies and the demographic densities have been increasing, the societies' Bloodshed Ratio (the ratio of the average number of killings per unit of time to a population size) has been nonlinearly but successively falling down. This paradoxical fact was first demonstrated with figures by the German sociologist of Jewish origin Norbert Elias (who had lost his relatives in the Holocaust and managed to escape from his motherland) in the late 1930s [29] and later confirmed by new independent anthropological, sociological and psychological researches [30-36].

Thanks to this historical trend, humanity in a whole, unlike many regional communities, has so far managed to rain in the increasing power of its tools. Yet, having accepted potentially unlimited capabilities of the technological intelligence, we are not ready to estimate confidently the perspective of its humanitarian constituent. What can play a fatal role in the destiny of Earth or any other planetary civilization are the incommensurable ranges of self-control – aggression-restraint and sublimation – and the natural power manipulation. Finally, any intelligence originated in a planetary evolution fails to restore its inner balances and destroys itself before it achieves the cosmically relevant stage. At best, we can suggest that very few technologically developed civilizations (perhaps, a single one) prove able to overcome the borderline between planetary and cosmic stages. The rest, as well as the biospheres that interrupt their evolution at earlier stages, remain universal evolution's waste products by implementing all of the deadlock strategies in universal natural selection. Will Earth civilization be among them?

Peace and War: The Diffusing Criteria

This is the way the world ends,
Not with a bang but a whimper.
Thomas Stearns Eliot

The "global crises" concept dates back to the 1950s; humanity was then on the brink of a nuclear war. Thanks to a series of unprecedented international compromises in the 1960s, a brittle military and political equilibrium was settled; psychological adjustment to the nuclear menace restricted the danger of a total catastrophe. Yet the shock experience which supplemented the tragedies of the two world wars increased awareness of planetary interdependencies, on the one hand, and anxiety about the future, on the other. Since the early 1970s, the attention of scientists and the public was reoriented on expected global risks. The unparalleled and geographically unequal demographic growth, the coming exhaustion of energy, sweet water and atmospheric oxygen and the other causes of apprehension became issues for passionate discussions.

The debates concerning current and predicted menaces essentially influenced politicians and the public and favored the satisfactory completion of the 20th century. Panhuman success was due to the fact that the main menaces had been discovered and overcome in proper time. New generations have not yet fully appreciated the greatest achievements like the mutual non-use of nuclear weapon, the ban on nuclear tests in atmosphere, hydrosphere and cosmos, and the global ecological measures. These were unprecedented breakthroughs, which have made possible our current existence. For the first time in human history, a new kind of non-confrontational political coalitions emerged, which were not aimed against an enemy agent, but cemented by a faceless (free from a subject for common hatred) threat of total collapse. This was the way human culture and psychology were adjusting to nuclear technologies, like long before they had adjusted to firearms, iron weapons, and so on back to the primary choppers by which Homo habilis used to crush one another's skulls 2.5 million years ago.

Nowadays, most papers on global prognostication either design an unconditioned and cloudless progress or turn us back to the late century conflicts (a recent brilliant example is mentioned in the beginning of this paper). Meanwhile, as we compare up-to-date global problems to large-scale historical precedents and analyze advanced scientific projects, we find reason to suggest that most of expected threats are potentially surmountable by means of "exponential technologies". This refers both to demographic growth, energy and other resources exhaustion (7.5 million hunters-gatherers were enough to cause ecosystem destructions and the biggest part of mega-fauna extinctions all over the Earth at the height of the Upper Paleolithic) and genetic burden accumulation, etc. However, each technology implies new menaces and respective dangers and risks caused by belated understanding. Their substance as a whole is not reducible to what humanity faced in the 20th century.

Thus, nuclear war risks have overshadowed a new unexpected menace that scarcely loomed up more than half a century ago: the lines between the conditions of peace and war started to blur. In our calculation, up to 25 million people died in the so-called "Cold" War, although we could register no more than four officially declared wars after 1945 and these were not the most large-scale or sanguinary ones (like the Honduras – Salvador "Football War" in 1969) [3]. Since the Nuremberg Trial condemned "war" as an outrage on humanity, most armed conflicts were accompanied by the inexhaustible euphemisms, sometimes rather absurd ones, like the "humanitarian bombardment" in Yugoslavia, 1999.

Since then, it has been more and more difficult to distinguish between war and peace, which was completed by the blurring lines between war and non-war techniques. The computer engineer, Bill Joy [37], noticed in 2000 that the weapon of mass destruction century was giving place to the century of knowledge-enabled destruction. Unlike the ballistic rockets and nuclear warheads, the newly developing technologies, every day cheaper and more available, are slipping out of governmental control and falling into the hands of irresponsible fanatics or of simply oafs.

Besides, after the bipolar world was destroyed in the 1990s, the state leaders' political thinking has been losing its quality as well. The grand masters of the 1950-80s have been replaced by lower-grade players without their predecessors' habit of estimating several moves ahead. The new leaders, therefore, are facing one boomerang effect after another on the international scene. Since the bipolar worldview conserved its dominance, this turned by a pathology of poles in the global geopolitics by the beginning of the new century. On one pole, we found the Western elites, still infected by the euphoria of "Cold War" victory and an irrational craving for new and new "small victorious wars" under the pretext of forced democracy spreading. The other pole, emptied after the USSR defeat, was filled by terrorist groups and gangs, the ones that had been cherished by the opposing military blocks in their time and then left alone by the bosses and thus grew wild. (Similar situations are well-known in ecology: for instance, after wolves are shot out, their niche is occupied by the feral dogs.)

The historical situation on the whole remains highly ambiguous. In 2003, the Royal astronomer of Great Britain Sir Martin Rees [38] appraised Earth civilization's chances to survive the 21st century as 50:50, which corresponded to our own scenarios at that time. Indeed, the 2000s were marked by the historical record of nonviolence: the UN and the WHO data reflected an unprecedentedly low Bloodshed Ratio, so that the overall violent deaths in international, everyday conflicts and political repressions during the decade were yearly less than the number of suicides [39, 40]. Yet, since 2011, further developments haven't followed the optimal scripts. A nuclear war is actually considerably less probable than it was in the 1950-60s, as far as humanity has adjusted to this menace. Yet in the developing technological and geopolitical situation, a global catastrophe can happen without a "world war" in its 20th century readings. Following Thomas Eliot's prophesy, we may grotesquely remark that the 20th century world could have ended with a "bang", while the 21st century can end with a "whimper". Most people will hardly realize the transition to history's "descending branch" in any of the imaginable scenarios, like a sliding down to the medieval condition and further back.

Today even more than ever before, the principal menaces are rooted in human minds. What we are facing now is not a "clash of civilizations" but rather a clash of the historical époques concentrated in the planet civilization's unique space-time. The past is often taking revenge (a hundred years ago Walther Rathenau called it "vertical intervention of barbarism", cited from [41, p.9]), which now shows the appearance of the symptoms of the approaching history's "descending branch". Religions and confessional distinctions cause confrontations, and the political vocabulary is overfilled with anachronistic schemas like "national interests" or "national future".

Our polling shows that politicians and political scientists can neither distinguish between concepts like "interest", "ambition", "caprice" and "profit" nor define "nation" amidst the growing interfusion of races, languages and religions. Consequently, the ambition of a powerful political leader, a dominant mass emotion or an influential corporation's profit is marked as the national interest. In fact, the excess of emotionally overloaded words with empty contents devalues the "patriotic" rhetoric and makes the quality of political discourse dangerously out of tune with the developing technologies. According to our observations, most politicians and their counselors aren't aware of how absurd a "national destiny" beyond the world civilization's perspective is. Content-analysis of the leading statesmen's speeches shows an obsessive link between words like "union" or "consolidation" and the word against. The enemies' crafty designs are central in the political argumentation again as a reaction to the side effects of the rectilinear "globalization" utopia.

The menaces in this century are related to the inertia of ideological thinking, which is traditionally based on the "them-us" matrix. From time immemorial, the image of common enemy has been a significant factor in social worldview and solidarity. It relatively restricted violence inside a tribe, chiefdom, state, confession or class by transferring aggression outside; at once, it served as the meaning-formation guideline. Meanwhile, the ideologies that agitated peoples in the 20th century have lost their motivation; this also includes liberal democracy stripped of its Protestant background. As far as many people feel uncomfortable beyond the "them-us" mental pattern, a search for strategic meanings is reanimating religious and/or national fundamentalism.

Life's Meaning: The Nucleus of 21st Century Global Problems

The new paradigm is the incarnation of a more optimistic view for the ones who are searching for life's meanings.

Paul Davies

Social-psychological experiments [42] have demonstrated that there is at least one alternative mechanism for both consolidation and meaning-formation: the image of common cause. This image doesn't assume an ill-intentioned enemy agent but rather aims at a joint work to overcome the natural chaos or the effects of humans' own thoughtlessness. We find it in the political experience as well: here, the grandiose compromises half a century ago should be remembered again. The great thinkers since the early Axial époque (about 2.5 thousand years ago) have been looking for the non-confrontational solidarity concept, so that cultural history brings us high standards of panhuman meanings beyond religious or quasi-religious ideologies. However, the masses' readiness to adopt such mental constructions has always been limited. Contrariwise, historical evidence is abundant that after a long period without real or potential wars, life's meanings dilute and the masses feel nostalgia for new demons and idols.

So far, besides being a resource for meaning-formation, intergroup conflicts have been social development factors as well, including the advance in humanitarian values. Yet, given the pattern of delayed dysfunction (see above), present-day technologies make this historical inertia fraught with a possible planetary collapse. Thus, life's meanings have become the nucleus of the 21st century global agenda. More specifically, the issue is about whether or not our minds prove ready to construct strategic meanings beyond ideologies and intergroup confrontations.

The fantastic époque we are living in has made all of the previous époques' material deficits potentially surmountable by the developing technologies: hunger and other vital discommodities are in modern world not so much due to the absence of products as to factors like war, blockade or overwhelming corruption. So more pressing has become the deficit of unifying meanings and values. To afford one more grotesque allegory, I would say that Cosmos is an inexhaustible source for such ones, and Big History may serve as an instrument for their abstraction. Indeed, although classical science was in its essence indifferent to human aims, values, meanings or destinies, these categories are essential in modern cross-disciplinary knowledge. Therefore, systematic outreach and awareness-raising may help develop planetary and cosmopolitan consciousness among both civil society and political leaders (by considering their professional properties).

This is the background for our practical recommendations.

Recommendations

While considering any event, let us ask
ourselves how it might be useful
in the following order:
1 for humankind,
2 for the motherland,
3 for one's friends
and family,
4 for oneself.
The origin of all of the evils that
surround us from the
cradle is our manner to turn
this progression backward.
Vladimir Odoyevsky

Scientists in various countries have lately been discussing calculations and respective hypotheses of the planetary Singularity. International meetings have been held and monographs and collections of papers published. The Singularity University (SU) started to function in the Silicon Valley in 2009 under the aegis of NASA and other organizations. The Center for Mega-History and System Forecasting (CMHSF) was founded in 2010 in the Institute of Oriental Studies, Russian Academy of Sciences. Similar institutions have been later formed in Japan and in some post-Soviet countries. In 2010 the International Big History Association (IBHA) was established from networking in the World History Association (WHA). Even earlier, since the early 2000s, respective cross-faculty courses have been taught in the universities of Europe, America, Asia and Australia, which gather hundreds of students in the lecture halls. Unfortunately, the two research lines – the one studying more the future and the other mostly turned to the past – are so far faintly connected. Still more lamentable is the fact that the relevant scientific discoveries have not yet attracted attention of either professional politicians or politically active citizens, though competently organized presentation might considerably influence many people's thinking and activities.

Our basic suggestion is to launch an international program for extending the web of clubs and public universities in order to discuss popularly global scenarios and to demonstrate humanity's inseparable destiny in the observable future. The job might be done under the aegis of the Global Challenges Foundation and other humanitarian institutions, including UNESCO. If the suggestion excites the experts' interest, the CMHSF in contact with IBHA and SU might gather an international cross-disciplinary professional group to prepare particular syllabi, learner's guides, audio-visual and other aids for popular cosmopolitan education. A relevant set of films, gaming and other artworks has been accumulated by the professional communities for more than fifteen years. Mass media, Internet-resources and opinion leaders in the informal webs and the mass and network communication psychological technologies are to be involved as well. The experience of teaching Mega-history (Big history), global prognostication and psychology of social security in various universities are to be synthesized at the preparatory stage. It goes without saying that the syllabi, didactic aids and methodic are supposed to be adapted to the audiences' cultural and religious traditions, educational attainments and professional interests. The standard syllabus might include the following subject directory.

1

The first subject scope gives elementary information about Mega-history. The teacher is to show graphically how the continual evolution of cosmos, Earthly nature and humankind has been lined up in a single, actually and potentially interdependent process. It is useful to demonstrate to what extent human body and mind, from the elementary reactions up to the most complex conceptual constructs, are related to our cosmic origin and to the evolution of life and culture.

2

The second subject scope includes a review of human history and prehistory emphasizing the dramatic relationship between the developments in technological and humanitarian culture. It should be shown how any new military or production technology entailed both privileges and menaces, what kind of catastrophes the misbalances between technological powers, on the one hand, and cultural and psychological self-control on the other, entailed, and how the advances in values and norms have provided societies' sustainability in spite of the growing destructive power of their technologies. Here, the story of the birth, evolutions, inner splits and compromises of the world religions, nations, and classes would be appropriate.

Great thinkers' and prophets' insights should be recounted, those that refer to the panhuman solidarity without group-versus-group confrontation, like the one by the 19th century Russian "Cosmist" philosopher in the epigraph; there are similar examples in many cultural traditions. Besides, it is high time to demonstrate to students and the general public why and how the role of individual decisions and actions in world causalities has been growing with the technological power.

To develop this subject scope, we suggest using the conception of anthroposphere as an antithesis to the bio-centric philosophy ("humans are an element of the biosphere"), which was very popular in the second half of the 20th century. That philosophy essentially promoted ecological consciousness, but later on it led its adherents into the deadlock of misanthropy. Anthroposphere is the background of the ecological philosophy in the 21st century. It is seen as a radically more complex system (compared to the pre-human biosphere) in which biota constitute the bearing substructure, and its control unit is human mind. Social-natural system's sustainability depends more and more on the conditions of the public consciousness, and the internal contradictions and disparities in its development are the chief reasons for natural and social calamities, which now threaten with the Earth evolution's breakup.

3

The third subject scope refers to the prognostic tree. Here, it is particularly important to take into account the disputants' educational attainment, qualification and prevailing values. Subject to these qualities, up-to-date calculations and data from the sciences and the humanities should be presented to demonstrate how absurd and utopian are the "separate" futures for the national or confessional communities.

Specific experiments and trainings will demonstrate how both human solidarity and strategic life's meanings are possible based on a cosmic perspective of the intelligence that has originated from Earthly humans development, without either the "them-us" contrapositions or the appeals to a Heavenly Lord. While working with mature and especially young politicians, it is worth appealing to their professional ambitions. The trainer needs to show them how those who first exploit the evidences of the next decades' crucial moment for world history in their programs and arguments beyond "national interests" and similar archaic stereotypes can gain determinant advantage and international public support.

The crisis of the simplified versions of "Globalization" requires particular discussion. The interventions of "advanced" states and governments in the "behindhand" peoples' life, on the one hand, and mass migrations into the richer regions, on the other hand, call forth growing protests both from the "left" and the "right". It seems important to show that what provoke uncontrolled mass migrations and sudden collisions among different historical époques with resulting cultural shock are, in most cases, just poorly thought-out interventions, including the military ones. Taking into account that globalization is the imperative for the modern world's survival, collective compromise programs are necessary; otherwise, the conflicts will most probably multiply.

Conceptually, this may also be supported by the synergetic system theory which supplements the Law of requisite variety by the Law of hierarchical compensations. The latter is as highly universal as the former one; it claims that the increase in a hierarchical system's aggregate variety results from the restriction of variety (unification) at its lower levels, and vice versa – the increase in variety at the lower level destroys the upper levels of the organization. In our case, subsequent social systems complication implies the growth of micro-group and individual varieties at the expense of diffusing macro-group (national, confessional or class) distinctions with commonly accepted panhuman values and norms.

Advisory support should be presented for Western politicians to form electoral programs and technologies that might be attractive for civil society and essentially increase their political effect. Work with "non-Western" politicians will require still more careful aid of competent analysts and opinion leaders.

In our tentative estimates, in case of the intensive involvement, the first organizational stage would take near half a year. Taking into account further approbation and corrections, the systematic campaign of full value might start a year later.

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The Unfolding of “Information” in Big History

Ken Solis

Abstract

This essay’s central thesis is that information and its “flows” are just as crucial as energy flow densities for the realization of increasingly complex systems over the course of big history. In fact, it is the requisite interplay between at least these two phenomena that make complexity possible. As with any endeavor of a philosophical or scientific nature, definitions are a crucial beginning point for building any argument. Hence, critical definitions will form an important basis for the content of this essay. If we assert that information plays just as essential a role as energy flows do for the realization of complex systems, then we must also propose the role information plays on a more basic physical level to support this contention. After all, complex systems don’t “spring fully formed from the head of Zeus like Athena.” Finally, and perhaps most importantly, we must have a better intuitive grasp of what information is or at the very least, what it does. As an example, physicists still don’t know what “energy” fundamentally is, just what it does, e.g., “energy is the capacity to do work.”

Keywords: Information theory.

Introduction – What *is* “Information?”*

The challenge posed in defining “information” is perhaps best reflected in a quotation from Claude Shannon (1916-2001), the widely acknowledged “father” of information theory:

> The word “information” has been given different meanings by various writers in the general field of information theory. It is likely that at least a number of these will prove sufficiently useful in certain applications to deserve further study and permanent recognition. *It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this*
> (Shannon, 1993, p180)

Inadvertently supporting his contention, luminaries from different fields of study have offered varied definitions of information. The following are just a few examples:

> “The ability to distinguish reliably among possible alternatives.” Claude Shannon, founder of information theory. (Schumacher, 2015, p6)
>
> “It from bit.” John Wheeler, renowned 20th century physicist. (Wheeler, 1990)
>
> “A difference that makes a difference.” Gregory Bateson, anthropologist (Bateson, 1972)
>
> “The difference between maximum entropy and actual entropy.” David Layzer, astrophysicist (Layzer, 1990, p28)
>
> “If information *is fundamentally relational*, then it makes sense that it is limited by surface area.” Benjamin Schumacher, quantum information pioneer and last graduate student of John Wheeler. (Schumacher, 1915b, p550)

I would suggest that Wheeler’s and Bateson’s definitions are pithy observations of what information *does*. In Wheeler’s “It from bit” claim, he is stating that information results in the genesis of the “things” or structures of the universe as particles and even the entire universe developed from patterned relationships. Bateson similarly is making the claim that information essentially causes or results in

* *My thanks to Bob Doyle, PhD, a former colleague of Eric Chaisson, and fellow protégé of astrophysicist, David Layzer. While Dr. Chaisson analyzed much on the ener*
of complexity, Dr. Doyle was more interested in information and philosophy (see www. informationphilospher.com). I am deeply in his

appreciate that my intuition about information’s importance had true merit and deepened my appreciation for this topic.

processes, or both. Layzer's definition, proposes a measure for the amount of information of a system, including that of the universe (Layzer, 1990, p28). Schumacher's definition, however, gets to the core of what information *is*. Similarly, Terrence Deacon, a neuro-anthropologist at the University of California - Berkeley, came to the same conclusion as Schumacher and matter-of-factly states, "information is about *the relationship of something to something else*." (Deacon, 2010, p159). Independently, but admittedly at a later date than both Schumacher and Deacon offered their definitions, I proposed that information is: "The relationships of entities in space-time." I added the phrase, "in space-time," because the scientific community has not come to a consensus as to what happens to information that enters black holes, where the known laws of normal space-time might not apply (Seife, 2007, pp 230-40).

Some Examples that Illustrate Why Information = Relationships

Here are at least a few arguments as to why information is fundamentally relational in nature:

- Imagine a very simple piece of information: for example, what is the location of a singular particle in otherwise empty space? Ultimately, in a 4 dimensional universe, you would give its coordinates (e.g., x_1, y_1, z_1, t_1) in relationship to something else, like the boundaries of space, its center, or perhaps another entity, plus some relation for "time," e.g., years since the Big Bang, the, the founding of Rome, the birth of Christ. In short, we also need a x_0, y_0, z_0, t_0 as reference (or relational if you prefer) coordinates. If a particle is simply present in a boundless, infinite space-time without any relationship to something else, you will not be able to give any information about its coordinates or even determine if it is stationary or moving.
- As Benjamin Schumacher points out in his Great Courses lecture series, *The Science of Information*, cosmic information has been postulated to reside on the surface area of the incredibly miniscule piece of space, about 7 x 10^{-70} m^2. Similarly, information is believed to exist on the surface or event horizon of a black hole (Schumacher, 2015a, p284). He pointed out that this makes sense, because it is the surfaces of the smallest possible "units" of space, or black holes that interacts or has relationships with the rest of the universe.
- Scientists are having a difficult time engineering a robust quantum computer because the "qubit" particles have to remain in a superpositional quantum state for it to work correctly. As soon as a qubit interacts (has a relationship with another part of the universe), it "decoheres" into a classical bit of information, i.e. it becomes a "1" or "0" rather than something, somewhere in between (Schumacher, 2015b, p499).
- .At the very beginning and end of big history - after the universe's possible future heat death - very little or no information will exist as structures even as simple as hadrons (e.g., protons, neutrons) might break down into random radiation (no patterns or structures), and no energy differentials are present to drive processes (Christian, 2011, p489). We will discuss information's relationship to entropy in greater detail later.

Despite the foregoing arguments and Deacon's implication that information's equivalency to relationships is obvious, not everyone has come to the same conclusion. After all, Claude Shannon, the "father" of information theory himself did not believe that any single concept of information would be satisfactory. However, despite his genius, Shannon may have been partially mistaken in this regards, if only because as Deacon again points out, *"This term is used to talk about a number of different kinds of relationships, and often interchangeably without discerning between them"* (Deacon, 2011, p152). I concur and believe that we must start with understanding and parsing at least the primary types of information before we can proceed forward.

Syntactical Information is the fundamental type of information that underlies all others and is, therefore, pervasive. Despite this basis, it is less intuitive to many people because our colloquial use of the term more commonly refers to other types of information which I will discuss shortly. Syntactical information, as I defined earlier, is about relationships. Hence, it can also be conceived as any pattern (a more static relationship) or process (a more dynamic relationship) of or between "things" that compose the constituents of the universe. As a parallel, in linguistics "syntax" refers to the rules of how different kinds of words (nouns, verbs, adjectives, etc.) are generally ordered for a particular language. Claude Shannon, a brilliant mathematician and engineer, was also amongst the first to understand that the task of designing communication technology was a challenge of accurately transmitting only syntactical information from one place or time to another. The *meaning* of the message is not relevant for engineering communication technology (Shannon, 1948). Engineers just need to develop the tools and processes to faithfully transmit patterns across time and space. The patterns can be variations in an electrical discharge as with Morse codes, variations in radio frequency amplitude as with some radio communications, alternating bands of black and white as with bar codes, and so on. Furthermore, information can transmute from one type of pattern to another and even between different kinds of medium. An oversimplified example can illustrate this chain of informational transmutations: A TV camera detects the photon emission pattern of wherever the lens is pointed; this photon pattern is converted to a pattern of electrical discharges, which is later converted to radio waves that are transmitted to a satellite; the satellite converts those waves to electrical patterns again, and then back to radio waves to be transmitted back to an antenna back on Earth. . . This general process of informational transmutations continues until your own TV transmits photons in a pattern very similar to the original source to your eyes. Still, this process continues via your central nervous system until "you" apprehend a satisfactory reproduction of the original image that might have occurred thousands of miles away!

Fundamentally, syntactical information also existed long before language and even life began – essentially since the Big Bang. *Natural* syntactical information is driven by many forces and processes, most importantly the three fundamental forces of the universe: (1) electrical weak force - often separated into electromagnetism and the nuclear weak forces, (2) strong nuclear force, and (3) gravity. Hence, the strong nuclear force causes quarks to relate to each other to form protons, neutrons, other particles, and atomic nuclei. The electrical weak force causes electrons to relate to nuclei to form atoms and molecules. Gravity, meanwhile, causes atoms, nuclei, and other subatomic particles to come together to form massive structures like planets, stars, and galaxies. Examples of *processes* driven by these same forces include nuclear fusion, photon emission, and the orbits of planets around a star, respectively. Other cosmic ingredients like dark matter and possibly dark energy are also relevant in the working of the cosmos although their nature is not understood at this time. The only thing we know about them is informational -- that they cause "ordinary" matter and energy to relate differently than can be accounted for by the known constituents and forces of nature. For example, dark matter was "discovered" when astronomers determined that there is not sufficient ordinary matter to cause galaxies and galaxy clusters to stay together. Dark energy was "discovered" when astronomers determined that galaxies are moving away from each other faster than can otherwise be explained. It is also important to realize that we do not even know if dark matter is matter, or that dark energy is energy -- the names are simply placeholders.

Semantical Information is information which has been processed by an *agent* so that it now has purpose or meaning for that or another agent. Per the Merriam-Webster dictionary, an *agent* is, "one that acts or exerts power." The question of when and how an "agent" becomes extant would easily consume an entire area of speculative science and philosophy, as can questions surrounding semantics itself (Floridi, 2011). For the purposes of this essay, however, an agent is a living organism that is able to act. (One might argue that artificial intelligence can also process information so that it can become semantical, but I will leave that philosophical discussion to the side.) A typical example of semantic information is the statement: "Please arrive at the Melrose Diner at 5 p.m. today." The letters are ordered in such a way as to form words that have meaning(s). The words are also chosen and arranged per the general rules of a language (syntax), so that one agent purposefully informs another that they should meet at a certain place and time. The import of the sentence above typifies what most people imagine when we say the word "information," although we would also include data transmitted and received by the internet, smart phones, television, books, and so on. Per the definition of semantic information, however, even sunlight shining on a "simple" plant has semantic informational content. The sunlight has meaning or purpose for the plant and might cause it to turn its leaves toward the sunlight to gather more energy for sustenance – even if the plant is not consciously aware of its actions.

Also, agents can create syntactical information instinctually, by intent, or accidentally, e.g., the utterance of sounds, a bear leaving claw marks on a tree, the release of pheromones, and so on. That artificial information can then become semantical for itself or to another agent. After all, the strips of missing bark on a tree are just that on the purely physical descriptive level. To a wandering bear, however, the missing strips of bark informs it that it has entered the territory of another bear.

Finally for our discussion, "novel," a.k.a. "pragmatic," information is that which provides new data to an agent and, thus, makes them aware, or at least more certain of a relationship of which they were not previously aware or about which they were uncertain. A classic example of novel information is when two lanterns were hung in Boston's Old North Church tower on April 18, 1775 c.e. to inform Paul Revere and others that the British were traveling by sea rather than by land to reach Lexington. The hanging of a chosen number of lanterns in the tower exemplifies what Shannon describes with his definition of information as "The ability to distinguish reliably among possible alternatives." In this case, Paul Revere had his uncertainty reliably reduced as to which route the British troops would travel. Novel information is a subset of semantic information because it also requires an agent, and not all semantic information provides new information to it, e.g., "the sun came up in the east this morning."

Information and Microstates

It might seem strange to consider an atom or a planet, for example, to in any way consist of information, but more sensible for them to be *described* by information, e.g., the planet's circumference is X kilometers, its mass is Y kilotons. However, physicists consider parameters like size, mass, temperature, and so on to be macrostate (~overall) properties of a system. According to thermodynamics, one of the principle disciplines of physics, a macrostate of a system is in turn determined by a corresponding number of possible microstates, which is how a system's microscopic constituents are arranged, interact, and behave. Temperature, for example, depends on the average kinetic energy of a system's molecules. A system with fast moving or quickly vibrating molecules has a higher temperature than one with slower moving or vibrating molecules. A system with closely packed molecules will have a higher density than one with more loosely packed molecules of the same kind.

Hence, how a system's microscopic constituents are arranged and interact with one another are its "microstate," and is synonymous with the relationships of its constituents, i.e. the information exchanged by its microscopic constituents in turn causes a system's macroscopic properties. It is this very type of information that is invoked in the famous Thorne-Hawking-Preskill wager: "Is the information that crosses the event horizon of a black hole (e.g., the mass, composition, particle motions, etc., of a star) lost to the universe forever or is it somehow preserved?" Although Stephen Hawking has contended that information is preserved, not everyone is convinced, including professors Thorne and Preskill (Gleick, 2011, pp358-9). Perhaps an easier to comprehend and accept example of a natural syntactical informational structure is the DNA molecule of a chromosome. Not only is DNA arranged in very particular patterns, it "contains" much of the information needed for the incredibly complicated functioning and reproduction of entire living organisms. (A little more on that later.)

Information – the Obverse of Entropy

As alluded to earlier, the flip side of a high degree of order or informational content is, roughly, a high degree of *dis*order. In thermodynamics, the degree of disorder or a system is often referred to as entropy. More technically, entropy is, "the log of the number of a system's microstates (or possible microscopic combinations) that can represent a macrostate (its large scale properties) (Stone 2015, p173). The fundamental formula for measuring entropy as described by the Austrian physicist, Ludwig Boltzmann (1804-1906) is: "S = k log W." "S" is entropy, "k" is a constant, and "W" is the possible number of microstates that are possible for a particular macrostate of a system. (If needed, see the side bar for a brief review of log functions.)

Very similarly, the simplest expression of the amount of information in a message is H = -k log M, where "H" is the amount of information, "-k" is a constant, and "M" is the probability of a message. Note that the equations given above are the simplest expressions of a measure of entropy and information, respectively. Slightly more extended formulas that cover more situations are typically used in the respective sciences, but the parallels between these formulas remain consistent, nevertheless. Also note that the values of "k" or "-k" do not mitigate the parallel either.

The similarity of the equations for information and entropy is not coincidental as was noted very early by Claude Shannon and other scientists. In fact, information theory was eventually used to successfully solve a century's old riddle in thermodynamics regarding a possible loophole to the second law of thermodynamics, called "Maxwell's Demon." In brief, in 1867 the famous physicist, James Clerk Maxwell (1831-1879), proposed a hypothetical way for a microscopic super-being to violate the second law of thermodynamics - which states that entropy of an isolated system always remains the same or increases. Attempts to disprove Maxwell's Demon using arguments from various areas of physics failed. By 1961, Rolf Landauer (1927-1999) proposed how information theory shows that the Demon cannot thwart entropy, and Charles Bennett (b. 1943) proved this conclusively in 1982. In the end they showed that it was the inevitable *erasure* of information that *must* incur energy costs, and hence would increase the entropy of any process in an isolated system (Seife, 2007, pp80-7). The main point is that information has been demonstrably proven to be essentially the flip-side of entropy or another aspect of entropy as some prefer to view it.

The laws of thermodynamics are also considered by many to be the most inviable laws in all of physics. The second law of thermodynamics is considered especially unassailable by physicists, including astrophysicist and philosopher Sir Arthur Eddington (1882-1944) who said, "The law that entropy always increases – the second law of thermodynamics – holds, I think the supreme position among the laws of Nature." (Seife, 2007, p34). Before proceeding, it should be restated that entropy of any *isolated* system must remain the same or increase – it can "never" decrease (a little more on "never" a bit later). Hence, it is possible to decrease the entropy of one part of a system, as long as that decrease is more than offset by an increase in the system's overall entropy. A star, for example, appears to decrease entropy or disorder when gravity causes the particles of a nebula to form a compact more organized sphere. That decrease in entropy is more than offset, however, by the subsequent emission of photons, neutrinos, and other particles back out into space (Chaisson, 2001, p73).

The apparent "force" of entropy actually stems from raw statistical power. To illustrate, let us look at a functional car as an example of a small system with low entropy. As already noted, entropy is the log of the number of microstates (e.g., assemblages of car parts) that can represent a system's macrostate (overall properties of a *functional* car). According to Toyota, a car is comprised of about thirty thousand (3×10^4) parts (see http://www.toyota.co.jp/en/kids/faq/d/01/04/). For a car to work properly, the parts must relate to each other in a limited number of ways. You could, for example, change the seats around, or switch the lug nuts and still have a functioning car. Let's be charitable and say that there are about 10^5 ways to assemble a car's parts so that it is still in a functional macrostate. While one hundred thousand ways to assemble a working car from thirty thousand parts might seem like a large number of permutations, the *possible* number of ways to arrange over thirty thousand parts is an incredibly vast number. The mathematical formula for the number of possible permutations is a factorial of thirty thousand, or 30,000 x 29,999 x 29,998 x 29,997 x . . . 2 x1. Consider this: if there were only sixty parts to a car, the number of possible permutations for arranging the parts is 8.32×10^{81}, about the same as the number of particles in the observable universe (Seife, 2007, p65)! No wonder it is far easier to take a car apart than it is to put it back together. Also, mathematically, a functioning car has very low entropy ($S = k \log 10^5$) when compared to a disassembled car with scattered parts ($S= k \log 10^{>>81}$).

It's important for us to note that entropy technically does not absolutely preclude the incredibly remote possibility of a car spontaneously forming all the right relationships to form a working car again. If the parts were floating in space in a box to keep the parts in close proximity, and an energy source was available to tighten bolts, etc., it is hypothetically possible for the car to come together again spontaneously to make a functioning car because the underlying physics are reversible. However, the statistical chance of this occurring is so miniscule, that the universe would long expire before there is a reasonable chance for this phenomenon to occur. Hence, the law that entropy "always" increases for a process, or a car "never" reassembles itself has a chance of being wrong, but it is statistically so miniscule that for all intensive purpose we can still say "always" and "never."

To further illustrate the mathematical statistical power of entropy, note that I only counted the large scale parts of the car and not the incredibly vast number of atoms and molecules that make up the car, and are also prone to other forms of disassociation from oxidation, ultraviolet light degradation, thermal motion, quantum fluctuations, etc. For example, if you included just the number of molecules in 3.5 tsp of water, the number of possible permutations for those molecules of water is over 10 to the 10^{th} power with 24 zeros after it. Now, imagine the number of molecules that constitute a car versus a teaspoon of water, and the number of possible permutations for the car molecules and atoms become incalculably enormous – the vast, vast majority being in a "nonfunctional-car macrostate." Nevertheless, somehow the forces inherent in our universe, made ever increasingly informationally rich structures and processes extant. Mathematically, H = -k log

M, where M, is the number of possible yes or no messages that define a structure or process (H). The more a structure's or process's constituents must be restricted or related, the more it is informationally enriched – the obverse of high entropy. Some people might even say that the structure or process is complex rather than informationally rich.

Complexity

Perhaps the most amazing miracle of our universe is that despite the seeming raw statistical power of entropy, complex organized structures like stars, galaxies, planets, life, and ultimately, brains capable of pondering such things came into being. Indeed, as David Christian points out in his book of big history, *Maps of Time,* "The endless waltz of chaos and complexity provides one of this book's unifying themes" (Christian, 2011, p511). Hence, to better understand big history, we also need to better understand complexity, or complex systems if you prefer. However, even at the Santa Fe Institute (SFI), which specializes in the study of complexity, there is no universally agreed upon definition for a "complex system." A few of the definitions offered by complexity science experts who were interviewed for SFI's 2016 online course, "An Introduction to Complexity," include (Note, some definitions below have been slightly condensed from their exact verbiage):

- "A system that has a very sophisticated internal causal architecture that stores and processes information." Jim Crutchfield, University of California, Davis.
- "A system that has interactions, nonlinear elements in it, and usually have scaling properties like power laws or fractal properties embedded in them." John Rundle, University of California, Davis
- "A system with a bunch of entities that may not start out being diverse, but end up being diverse, are connected in some way (usually a network structure or some spatial structure), and they get information through that network or spatial structure, but also sometimes get some global signals or information." (whew!) Scott Page, University of Michigan.
- "A system with many interacting components and the interactions between the components have nontrivial or nonlinear interactions and that leads to a system having unpredictable behavior." Stephanie Forrest, University of New Mexico
- "A system with a lot of interacting parts where something about the way those interacting parts behave is qualitatively different than the way they behave if you look at them individually." Doyne Farmer, University of Oxford
- "A system that contains enormous numbers of actors or agents that are interacting usually in a nonlinear fashion from which all kinds of multi-level behavior evolves so that there are emergent phenomena." Geoffrey West, Santa Fe Institute

What is common to all of these definitions is that they depend on describing various properties of a complex system, rather than a single, core characteristic. Indeed, noted big historian professor, Fred Spier, states in his book *Big History and the Future of Humanity*, "Because no generally accepted definition of 'complexity' appears to exist, I decided to tackle this problem by making an inventory of its major characteristics" He goes on to state, ". . . a regime is more complex when more and more varied connections and interactions take place among increasing numbers of more varied building blocks." (Spier, 2015, pp48-9). Resorting to a definition based on characteristics, is not unique to "complexity," because "life," and "civilization," complex systems in themselves, are also defined by their properties, e.g., "life" is something that is able to metabolize, reproduce, and evolve. In regards to key characteristics of complex systems, at least two of the definitions from SFI faculty included the term "information." Nearly all the rest, including Spier's definition, include the terms "interacting" or "interactions," which is synonymous with the transfer of information from one entity to another - whether those entities are electrons exchanging photons with the nucleus, or the brain's hypothalamus interacting with the pituitary gland, which interacts with various other glands of the body. In other words, all of these definitions explicitly or implicitly include "information**"** as a key characteristic of complexity.

Note that none of these definitions included any mention of increased energy flow density through a system as an essential property of complexity, which Eric Chaisson convincingly demonstrated in his oft-cited book, *Cosmic Evolution* (Chaisson, 2001, p13). The exception is Spier, who does later discuss Chaisson's observation on this aspect of complexity (Spier, 2015 pp 53-64). Of course, the absence of "energy flow density" in those interviewed by SFI does not mean that Chaisson is amiss in noting and analyzing this phenomenon. It is more likely that he has discovered and quantified a unique and laudable insight into one of complexities key characteristics. Nevertheless, Chaisson also states that complexity can also be operationally defined "as a measure of the information needed to describe a system's structure and function." (Chaisson, 2001, p13). Hence, it is apparent that there is widespread consensus that information is a defining characteristic of complexity, even if it is often guised as "interactions." I will also assert that while energy flows are necessary for complexity to occur, it is not by itself sufficient. Information is also necessary and just as fundamental, if not more so. Consider: regardless of how finely tuned or how much energy is made to flow through the mended corpses that made up Frankenstein, the monster will never come to life. Too many proteins have denatured, the blood has clotted, neurons have withered, and too many cell membranes have lost their integrity. In short, the many critical relationships or informational content of the body have been lost to entropy, and reanimation is not even remotely possible.

Therefore, it is the interwoven dance of at least the three fundamental ingredients of the universe: mass/energy, fields of force, and information that makes complexity possible over the course and stage of space-time. It might be that there is yet some other ingredient(s) that eventually made complex structures and processes like life and minds possible. The origins of these ultimate expressions of information and complexity have yet to be fully satisfactorily explained although complexity science is especially working hard to understand the origins and aspects of complex systems. While acknowledging that I am not giving complexity science the attention it deserves, I propose that we nevertheless, go forward and look through an information-centric lens to examine at least a few of the phenomena that have transpired through big history.

The Big Bang – and then there was "1"

Claude Shannon is credited with, along with many other aspects of information theory, determining that the most basic unit of information is a "bit" that is often represented by a binary digit -- a "0'" or a "1." A binary digit in turn represents any dichotomy such as "yes" or "no," "black" or "white," and even "existent" or "nonexistent." By analogy, we could state that at the instant of the Big Bang about 13.8 billion years ago, the cosmos went from a "0" to a "1" – John Wheeler's ultimate "It from bit." Still, the amount of information of the universe at 10^{-43} seconds was "0" because the logarithm of 1 in any base is that value. Intuitionally this makes some sense because the initial completely undifferentiated nascent universe was also indeterminably small, and indeterminably hot (Fewster, 2016, p35). In fact, it was so hot that there weren't even any "particles" to form relationships and, hence, informational content.

According to current cosmological theories, the fundamental forces of nature, gravity, strong nuclear force, electroweak force, and then the 13 various fundamental particles of the standard model like quarks, photons, electrons, etc., all "precipitate" from the early roiling universe between 10^{-42} seconds and 10^{-6} seconds (Fewster, 2016, p34-5). With each new "ingredient" to the universe, the informational content would seem to increase by some vast new quantity. In fact, physicists estimate about 10^{80} fundamental particles exist in the observable universe (Seife, 2007 p65). However, the estimated informational content of the universe is calculated to be somewhere between 10^{90} and 10^{120} bits because you must also include other parameters like the particles' velocities, spin, mass, etc. (Schumacher, 2015a, p287-8).

An early example of interactions creating information is when hydrogen (~75%), helium (~25%), tiny amounts of deuterium (.01%) and even less lithium nuclei formed by about 3 minutes after the Big Bang (http://w.astro.berkeley.edu/~mwhite/darkmatter/bbn.html). It is worthwhile noting that physicists are not in total agreement whether information can be technically created or destroyed. However, at least new "kinds" of information or new relationships occur over time. The quarks and gluons are now interacting in novel ways to comprise protons, neutrons, and combinations of them to form atomic nuclei. It is also worthwhile noting that the information increase caused by the formation of these components is not predicted by "H = -k log M," because this formula works only if there were 2 different components that occurred with equal probability. The more general formula for the information content for an event that occurs with a different probability than a flip of a coin, i.e. other than a 50:50 chance, is "H = -k log 1/p(x)" where "p(x)" is the probability of event "x" occurring (Stone, 2015, p36). This variation of informational quantity is also sometimes referred to as the "surprise" and often abbreviated as "s(x)" rather than "H." To rephrase as Shannon might have stated: "The greater the surprise of a message, or the less likely it is to occur, the greater it reduces informational uncertainty." In the parlance that I have been proposing, improbable information is also very "novel."

This assertion is nicely illustrated by noting that the observed ratios of deuterium (one proton and one neutron in its nucleus) and helium nuclei that astrophysicists observe in interstellar space are the same as those that they calculated would have formed during a brief period early after the Big Bang: 0.0001 deuterium and 0.23 helium, the remainder being hydrogen and a tiny bit of lithium. (http://w.astro.berkeley.edu/~mwhite/darkmatter/bbn.html). The high "surprise" of that small presence of deuterium ($\log_2 1/.0001 = 13.29$ bits) helped to convince many cosmologists that the proposed Big Bang model was correct, i.e. the rare occurrence of deuterium and its accompanying high informational value was strong evidence that their theories were correct. Adding the informational "surprise" of the correct amount of predicted helium further substantiated the Big Bang theory ($\log_2 1/.23= 2.12$ bits), but not as much as detecting the predicted small amount of deuterium – at least from a purely informational theory perspective. (Note: for simplicity, the "-k" value was ignored as it is in many sources because it does not change the conclusions.)

The End of the Dark Age – Information Gets to Travel!

If the proportion of deuterium to "regular" hydrogen and helium nuclei is disproportional, consider photons. Photons, one of the fundamental particles of the universe, outnumbered quarks and other particles by a factor of at least 1 *billion* to one after the annihilation of particles and anti-particles ceased about one second after the Big Bang (Christian, 2011, p25). Those photons and their distribution are represented by the "cosmic microwave background" (CMB) which was famously discovered by Penzias and Wilson in 1965, and later mapped by the COBE and WMAP satellites. The

CMB does not represent the "same" photons from the first moments after the Big Bang, but rather those that began to scatter 380,000 years later when the universe had cooled sufficiently to allow the freely roaming electrons to be captured by the nuclei to form complete atoms (Fewster, 2015 p34). With the capture of free electrons, the photons were not continually being absorbed and reemitted after traveling short distances. Now the photons could travel unimpeded not only through space, but through time as well such that some of them ended up on the radio antenna of Penzias and Wilson, or the detectors on board the COBE and WMAP satellites. This event 380,000 years after the Big Bang is called the end of the cosmic "dark age" (Spier, 2015, p90).

The photons that travelled through time and space for ~13.8 billion years to land on our detectors, not only gave us information about that event, they also demonstrate another feature of information – the fastest at which it can travel. Due to the constraints of known physics, the fastest that *anything* can travel is the speed of light through vacuum, about 300,000 kilometers per second. Another way to think of this fact is that nothing in one part of the universe can affect or relate to another part of the universe sooner than it takes a photon to travel that distance. As a side note, it is interesting that especially in the past, historians referred to time periods when there was paucity of or a decrease in information as a "dark age" such as the Greek or Medieval Dark Ages. In other words, we intuitively, or coincidentally at least, associate light with information.

Also, the estimation that only 1 in a billion elementary particles are *not* the nearly evenly scattered photons of the CMB indicates that a great amount of the universe's entropy was "created" right after the Big Bang. Besides being the obverse of information, entropy is also a measure of energy that is not available to do work – and energy to do work is necessary to make complex systems as Chaisson rigorously pointed out. Despite such a large dissipation of energy in the first moments after the Big Bang, there were still enough energy differentials and concomitant low enough entropy to drive the creation of complex entities from stars to rain forests.

Increasing Complexity - the Gift of Information, Energy Flows & Time

Over the next approximately 10 billion years, the fundamental forces and particles created after the Big Bang with the added assistance of dark matter (whatever that is) went on to form stars ca. 13.6 billion years ago (BYA), super nova ca. 13.5_{BYA}, galaxies 13.4_{BYA} (Fewster, 2015, pp44-5), and at some point in time, planets. Note that the sizes of these structures ranging from small asteroids to the eventual galaxy superclusters are vastly larger organized structures than the preceding atoms or nuclei of the primordial gas cloud. Gravity was the instrumental force for creating these much larger and more complex entities. At first, glance, this increase in order would seem to be a contradiction to the second law of thermodynamics which indicates that entropy will remain the same or increase with the passage of time. Recall, however, that *local* entropy can decrease as long as the universe's (the ultimate "isolated system") overall entropy increases.

Restated in terms of information, stars and galaxies require much more information to describe their structure and processes than would a similar amount of an amorphous gas cloud – like a nebula. Although, it would take a great deal of information to describe the relative positions, directions interactions, speeds of travel, compositions, etc. of each of the nebula's particles, it would require even more information to describe those same parameters, plus their ordering, more varied density, new interactions (informational or relational changes), and newly created particles, like carbon to name a few. This kind of analysis, although to a much more profound depth, led Erwin Schrödinger (1887-1961) of quantum mechanics fame, to call this process of localized ordering and informational increase as "negative entropy" in his book *What is Life?* (Schrödinger, 1967, p71).

The phrase was later shortened to "negentropy" by another physicist Léon Brillouin (1889-1969), in part to avoid the word "negative" with its associated connotations (http://www.informationphilosopher.com/solutions/scientists/brillouin/).

As briefly alluded to above and importantly for the future of complexity, stars increase the variety of nuclei, and eventually atoms, by forging elements up to iron in their cores, and elements up to uranium when they explode as supernova (Fewster, 2015, p63). Although the vast majority of elemental atoms in the universe are still hydrogen (about 90-92%) and helium (about 8-10%) (DeGrasse Tyson, 2004, p. 72), the remaining ~1% of the other approximately 90 natural elements are critical for the eventual creation of evermore complex structures and processes. The addition of the extra elements allows for a tremendous increase in the number of new possible relationships as the elements can combine with each other in innumerable ways – especially carbon which can form 10 million or more combinations with itself and other elements. Carbon also happens to be the highest element that can be forged in a star the size of our sun.

Life – Complexity takes Information Really Seriously

Although there are admittedly remaining profoundly important mysteries, we can satisfactorily explain much about the structures and processes of the universe with the known constituents and forces of physics and chemistry. Indeed, especially to a non-physicist like myself, it seems a staggering feat of accomplishment that scientists can accurately predict the magnetic strength of an electron to the 12^{th} decimal place (Pollock, 2001, p121), postulate what happened at 10^{-30} second after the beginning of the Big Bang, and so on. Nevertheless, another complex system that still defies satisfactory explanation confronts us every day we look in the mirror, play with our pet, or even squash a mosquito – life. Also, if you are still skeptical about information playing a real role in complexity, life is the phenomenon where Chaisson's energy flow density via metabolism more obviously entwines with Shannon's informational flow via reproduction, evolution, and other functions of DNA and RNA.

But how did energy and informational flows come to be so complex in themselves, while also complexly entwined? Although hypotheses abound as to how life generally came to *be* shortly after the Earth cooled sufficiently for it to exist, no current theory satisfactorily entirely predicts how this complex phenomenon not only originated, but persisted and spread to a truly remarkable degree. David Christian said it well, ". . . but at the biological level of complexity, new rules appear as well. Living organisms operate according to distinctive and more open-ended rules of change, which are superimposed on the simpler and more deterministic rules of physics and chemistry." Also, "So to understand living things, we need a new paradigm, one that takes us beyond the rules of nuclear physics, chemistry, or geology and into the realm of biology" (Christian, 2011, p81). Professor Christian also seems to give primacy to high energy flows as the defining characteristic of complex life: "The rules of biology are made possible by the high degree of precision with which living organisms reproduce. Handling large energy flows are such a delicate task that it requires extremely precise mechanisms; the rule book for creating and re-creating such structures has to be complex, exact, and accurate" (Christian, 2011, p81). Admittedly, metabolism is one of the defining features of life and it has all the features that Christian mentions. However, I would assert that the information needed to realize the complex mechanisms of metabolism, as well as reproduction and evolution is co-equal to energy flows, if not paramount.

Admittedly, it is unlikely that complex interactions or information flows of complex systems would be possible without the other – high, finely tuned energy flows. They are tied together like a Gordian knot. An organism perishes when either energy flows are insufficient (e.g., insufficient food, cyanide poisoning), or information flows are disrupted (e.g., neurodegenerative disorders, proteins denatured by high temperatures), or both (e.g., respiratory or circulatory failure). Nevertheless, aging and death itself is inevitable, not primarily due to failing energy flows, but because of the inexorable march of entropy which causes complex relationships to steadily degrade over time: the skin wrinkles and sags, the hair greys, bones become brittle, and, yes, the heart's output declines as well, but typically due to various changes in its tissues.

Yet, on the other hand one of the most profound miracles of life is that it can also repeatedly and faithfully renew its information virtually unchanged via reproduction despite entropy, even over billions of years as in the case of bacteria or archaea. A miracle of similar magnitude is that life has also diversified its informational content into literally 100's of millions of species over time, and with even greater degrees of complexity via evolution. That is, the information of life can both replicate itself accurately, while also occasionally varying its replication such that it has also increased its depth and breadth over time. In the final analysis, it would seem that life especially exemplifies that energy flow is the hand maiden of informational flow. If still in doubt, consider viruses – packets of information that hijack a "true" life form's metabolism to reproduce itself. Note that there is no known equivalent entity constituted primarily of an energy structure like a mitochondrion that hijacks a true life form's informational contents to reproduce.

Admittedly, one of the advantages of energy flows in complex systems is that it is more readily calculably quantified – and scientists are often understandably enamored with mathematics and its quantitative predictions. Even from an informational centric viewpoint this love affair makes sense: math is but the very precise pronouncement of how relationships work and often makes these pronouncements much more scientifically testable. While energy flow densities can sometimes be precisely predicted and stated in mathematical terms, the mathematics associated with information theory often predict limits rather than exact quantities of informational content, change, effects of noise (informational interference), and other parameters.

One example of information theory's ability to predict limitations is in regards to determining the minimum number of symbols or codes needed to convey a message. To illustrate, DNA is fundamentally a set of codes that directs the reproduction and many of the functions of living organisms. One very common type of DNA based instruction is how to sequence any of the up to twenty amino acids available to make particular proteins. To determine the minimum number of bits required to represent or code for these twenty amino acids, you must also have a code for the command to "start" and "stop" making the protein. To determine the minimum number of needed codes, you take the $\log_2$ of twenty-two, which equals 4.46 bits. Pragmatically, you can't use 0.46 of a symbol to represent a bit, so DNA has to round up to at least five bits to represent the twenty-two necessary codes. As it turns out, DNA uses four different nucleotides abbreviated as A (adenine), G (guanine), C (cytosine), and T (thymine) in sets of three to comprise those codes. For example, the DNA code "GGU" represents the amino acid glycine. The possible number of permutations of four nucleotides in sets of three is equal to 4^3 or sixty-four. The $\log_2$ of sixty-four is six bits. Six bits is greater than five bits, which means that the DNA coding for protein synthesis satisfies the rule for the *minimum* number of codes necessary for a message, which in this case is a completed protein.

If nature was solely concerned with efficiency, it might have instead chosen to use codes comprised of five nucleotides in sets of two, which gives you 2^5 possible codes or exactly five bits. However, life has to worry about more than efficiency. As

Shannon would state, life also has to contend with the "noise" in the signal channel. In this case the cellular cytoplasm for prokaryotes (bacteria and archae) or the cell's nucleus for eukaryotes (other life forms) is the communication channel, between DNA and the environment. Reactive chemicals, radiation, and thermal motion, to name a few factors, are some of the sources of noise that can cause an unintended change in DNA's code sequences. Having six bits of code rather than the minimum five bits allows for increased redundancy in the code so that not all noise induced changes of the DNA (i.e. mutations) lead to potentially harmful alterations in protein synthesis. Glycine, as an example, is symbolized by GGG, GGA, GGT, as well as GGU. Similarly, other amino acids and the "stop-making-the-protein" codes are also represented with several similar sequences. Hence, an inadvertent change in one nucleotide does not always result in the dysfunction or even death of an organism from an altered protein.

Information theory can also provide other insights into life such as why the exchange of DNA via sex might have evolutionary advantages over relying primarily on mutations as in asexual organisms (Stone, 2015, pp.188-193), and the upper limits of mutations that early precursor molecules for life would be able to tolerate without failing to reproduce – the so called Eigen error catastrophe. (Schumacher, 2015, pp156-8). However, at this time at least, we must concede that there is not a quick, clear correlation between the number of genes, which are rough "units" of DNA information, and the complexity of an organism. A recent study, for example, determined that the human genome contains less than 20,000 genes, which is far fewer than that of a water flea which has 31,000 genes (https://www.popsci.com/article/science/humans-may-have-fewer-genes-worms). Even though this apparent paradox might be explained by other factors such as it is also *how* genes are controlled by non-protein coding regions of DNA that defines an organism's complexity, an easy and seemingly obvious metric for measuring the complexity of an organism is not as readily available as Chaisson's energy flow densities – at least at this time.

The Brain – The Ultimate in Complexity and Information Processing

If complexity is best measured by energy flow density, then the brains of humans and other "higher" animals surely qualifies as among the most complex systems based on that metric alone. As calculated by Professor Chaisson, the brain uses about 150,000 ergs/sec/gm whereas the body overall uses about 20,000 ergs/sec/gm, or about 7.5 times the body's average (Chaisson, 2001, pp138-9). However, the design and purpose of the brain is not to simply expend energy, but rather to access, process, store, and transmit information. Again, energy flow is serving the needs of information flow for both the design and function of a complex system.

The biological-based neurosciences and information sciences have gone a long way to describe many of the secrets of how the brain works. We know much about what area(s) of the brain serve which functions, how stimulated neurons transmit electrical potentials down their length to cause the release of varied chemicals at its far ends to pass on a signal to the next neuron, that the brain can only process and retain about 2.5 bits of one type of sensory information at any given moment (Schumacher, 2015a, p171), and so much more. In fact, there is a sophisticated level of research called "computational neuroscience" dedicated to applying information theory to the workings of neurons and large neural systems (Stone, 2015, p195).

Nevertheless, when you consider higher functions of a brain as advanced as a human's, we still have a "black box" of complexity from which emerges incredibly surprising phenomena like self-awareness, emotions and other subjective experiences, future anticipation, past reflection, and abstract problem solving to name a few. If you were some disembodied, detached super-physicist present at the Big Bang, would you be able to predict that the various fundamental particles and forces of nature could relate together in just the right way to eventually create such strange phenomena? Furthermore, while these higher functions remain a fundamentally deep mystery, it is much more likely a manifestation of informational processing, integration, and feedback loops, than a result of finely tuned energy flows, even if the latter is a prerequisite.

Humans Take Information and Complexity for a Ride

One of the most important "tricks" of the human brain is its advanced ability to turn syntactical information into semantical information. To reiterate from earlier, syntactical information is the raw ordered structures and processes "out there" in the world, whether it was created by a natural process or another "agent." The human ability to apprehend syntactical information, process it via the brain, give it rich semantical content, and then communicate that information to others was possibly the single greatest set of related abilities that led to us eventually dominating the planet – for better and for worse. As mentioned earlier, semantics began when the first organism detected something within itself or in its surrounding environment, and responded to it in some manner, e.g., it sensed a depletion of nutrients and slowed its metabolism. At this simple level, you might feel that it is a stretch to claim that the syntactical information it gained from its environment caused a simple organism to "purposely" slow energy expenditure when the information flow was likely a fairly direct, even if long, sequence of chemical reactions. However, as life diversified, some forms increased the complexity associated with detecting, processing, responding, and eventually becoming aware of at least some information to which it was exposed. Subsequently, the meaning of semantics becomes ever more meaningful in itself. Somewhere during evolution, at least by the time a central nervous system develops, it becomes ever more difficult to trace a clear path of syntactical relationships from sensory input to some output that doesn't beg us to identify other phenomena, like awareness, anticipation, memory, etc. Information becomes not just a series of morphing relationships, but morphs itself into an agent for which information of its external and internal environment carries ever deeper, and dare I say, more complex meaning.

Humans seem to be the epitome of conscious agents and are able to give semantical content to even the simplest syntactical sensory data. Religious symbols, national flags, and the musical notes of "Taps," are but a few examples of humans communicating abstract, rich information from one to another via fairly simple symbols or signals. The beginning of this "symbolic thinking" began for certain by the time of the earliest cave paintings around 38,000 b.c.e. (https://www.nytimes.com/2014/10/09/science/ancient-indonesian-find-may-rival-oldest-known-cave-art.html). It is possible, however, that it began as early as about 80,000 b.c.e. as suggested by the presence of ochre, likely used for body decorative purposes, that was discovered in a cave in South Africa (http://www.nytimes.com/2002/02/26/science/when-humans-became-human.html).

The earliest evidence of symbolic communication is visual because pigments on walls, or materials like ochre in protected areas were able to survive the passage of considerable time. However, humans have historically used complicated and ephemeral sounds to communicate most of its information to others, and likely did so at least as early as our use of visual symbols. Despite its transient nature, the choice of using varying sound waves to communicate makes sense from a physics and environmental perspective. First, sound travels quickly, about 1,000 feet or 330 meters per second. Another option might be odors, but the speed of travel would be limited by wind speed and thermal motion. Another option would be the fastest possible option, light. However, light waves are easily reduced or entirely blocked by common things in the terrestrial environment like plants, rocks, and hills. Also, because we don't have an organ or tissue that emits light, like a firefly or angler fish, communication by this modality doesn't work in the dark of night. Touch, another sophisticated sense, is used for some communication, but is obviously limited in extent by one's reach. Therefore, the speed and transmissibility of sound make it a good choice for warning, finding, and generally informing others.

The human body is also designed to emit a much larger variety of sounds than light (e.g., skin color change) or odors (e.g., pheromones) and, therefore, can communicate a much greater variety of messages which can even be nuanced by inflection, musicality, loudness, sound order, and other variables. Finally, we can change and exchange the utterance of sounds much faster than we can change colors or odors. In the parlance of information, the ordered utterance of changing sound waves allowed for the faster and omnidirectional communication of bits of information through space with less interference from background noise. It also allowed for a greater diversity of bits of information to be quickly communicated. Finally, although various species communicate to each other by changes in light waves or patterns, odors, touch, various sounds, and sometimes by even other means (e.g., bioelectrical fields), it was the progressive evolution of an ever richer use of sounds that would eventually become "language." The semantical richness of language in turn made us capable of a much greater range and depth of "collective learning" compared to other life forms (Christian, 2011, p146-7).

But still, there is that ephemeral problem. While sound travels well through a reasonable range of space, it does not travel well through time. Oral traditions do mitigate this problem, but rely on the memories of a chain of individuals which can introduce a significant amount of noise so that the original information becomes corrupted, as it commonly does with social gossip. Humans developed techniques to reduce the noise of memory through the use of meter, rhymes, repetition, musicality, and other means to better communicate lengthy bits of information, like the Homeric epics, to later generations (Gleick, 2011, pp34-5). Still, having an informational medium as rich as vocal sounds, but as long lasting as visual signs would potentially convey much more information, with less alterations from memory noise, to more people over longer periods of time. In other words, it would be nice to have a way for the collective learning from one generation to be more accurately and extensively passed onto the future ones. Restated as the core central theme of this paper, it would be advantageous for humans to be able to more permanently, richly, extensively, and reliably communicate learned relational data to others over greater distances of space as well as time. Enter the written language.

Creating a rich written language is a rare and apparently difficult achievement. It was created from "scratch" only three, possibly four times in human history: by the Sumerian, Chinese, Mayan, and possibly the Egyptians. Whether Egyptians developed writing independent of Sumeria is a matter of contention among historians (Parker, 1986, pp50-1, 262). As you can tell from the names of its originators, the development of writing apparently requires a "high" civilization as a cultural milieu. Civilizations in turn are dependent on the development of agriculture. Writing or even other forms of semantically rich visual communication, like the Inca knotted ropes (Quipus) never began in hunter-gatherer or pastoral nomad societies. This sequence of events nicely illustrates the interplay that occurs between information and energy flows for promoting the development of complex systems. To wit, agriculture's primary role is to increase the availability, reliability, and locality of energy flows from the sun to humans via the cultivation of plants, and the utilization and consumption of domesticated animals. This increase in energy flow, in turn made possible the development of civilizations, which used this energy to increase its relational or informational complexity via a more divided and hierarchal social structure, increasingly sophisticated material goods, and grand architecture, to name a few of its salient features. Civilization in turn found it necessary to develop a better way to record information for pragmatic purposes like inventories, taxation, the coordination of work or war projects, as well as for spiritual, aesthetic, and other reasons.

Writing went through substantial improvements over its subsequent history in regards to its cost, portability, decreased errors in reproduction, ease of manufacture and access. Think clay tablets versus papyrus or paper, scrolls versus codex, and writing advancements like the invention of the alphabet, word spacing, Carolingian miniscule, and punctuation. Perhaps the most important improvement responsible for propelling the next great leap in human social complexity was the invention of the printing press by the Chinese in the first century, c.e. (Fewster, 2016, p267) which was then improved further by the European, Johannes Gutenberg, around 1440 c.e. The improved the printing press together with the more printing-press-friendly Western alphabet, subsequently increased collective learning by several magnitudes for all the reasons given above. Once again the invention of the Gutenberg printing press and the subsequent sequence of major events help to illustrate the interplay between energy and informational flows that can occur and result in increased complexity.

First, the printing press fundamentally made information flows through societies much more efficient, and thereby pervasive. Arguably, the first major impact from the printing press was its effect on the Catholic religion in Europe. The widespread printing of both diversified religious views and the Bible itself into its traditional Latin as well as vernacular languages made it essentially impossible for the Catholic Church to monopolize Biblical information as it had before. Subsequently, it could not fully quell the informational variants of the "word of God," (heresies) as it had with earlier movements like the Albigensians, Gnostics, Monophysites, and others. This spread of diversified religious information in Europe certainly did add new complexities to the political and spiritual structures and processes of the continent, not to mention the catastrophic Thirty Years' War (1618 - 1648). However, it would likely be hard to argue that the increased European religious diversification that was promoted by the printing press created any novel social complexities that weren't already present in other locales, even within Europe. For example, the Iberian peninsula had long been religiously diversified with Muslims, Christians, and Jews living together under the Umayyads. the Indian subcontinent in particular was already host to an even more diversified mixture of Hindus, Muslims, Jains, Buddhists, and the early Sikhs. Complexity changed at a much greater rate, however, when books helped to both precipitate and more quickly disseminate two of the major revolutions in human history: the scientific and industrial revolutions.

The scientific revolution was informationally driven. Although, a more rigorous scientific way of understanding the world had earlier beginnings, like Copernicus' (1473-1543) publication of *De revolutionibus orbium coelestium* in 1543, it arguably began in earnest with the empirical studies of Galileo (1564-1642) and the printing of Francis Bacon's (1561-1626) *Novum Organum Scientiarium*. Both of these events occurred in the first quarter of the 1600's and modern science gained steady momentum from that time forward. Importantly, Galileo's work and Bacon's treatise demonstrated and carefully explained, respectively, a more rigorous way to determine if a rational proposal about how the universe works does indeed coincide with reality empirically. In raw informational terms, does 10111 "+" 01001 "=" 1011101001 *as predicted* or not? (Note: this example is purely fictional and oversimplified, but simply meant to illustrate a general point.) Once the works of Galileo and especially Isaac Newton (1642-1727) proved the success of this approach, major shifts in informational authority (e.g., church versus scientific community), the rate of progress, and institutional changes began to accelerate. Information flows were also augmented by extending our senses, at first visually with the inventions of the telescope and later the microscope. Later inventions not only augmented the information we gain from our existing senses like hearing, sense of time and direction, but also extended our ability to gain information from phenomena that are entirely removed from our senses, e.g., radio waves, magnetism, radioactivity, x-rays.

Another important "revolution" that must be mentioned, even if only briefly because of its huge impact, is the "Columbian exchange." That is, the beginning of the first truly global exchange of information, people, and materials that began with Columbus' voyage in 1492. The exchange rates, variety of items, and trade distances would quickly eclipse those of earlier trade networks like the "silk road." To some extent even energy flows increased somewhat as calorie rich crops like the potato and sugar cane were cultivated in new lands.

The Modern Age – Information & Energy Positive Feedback Loops

Still, the scientific and Columbian exchange revolutions did not appreciably change the day-to-day lives of the great majority of people in the Old World (Christian, 2008, p220). While a myriad number of reasons for a greatly accelerated rate of change can be forwarded, the key reason is the onset of the industrial revolution in the mid-18th century. England, the first industrialized country, added a substantial increase in energy flow rates with the invention of the steam engine and many other inventions that harnessed the energy of its readily accessible coal.

With the already extant printing press, a more widely educated population, global exchange networks, and scientific method, a positive feedback loop was created where an improvement in one invention led to a cascading fount of other improved and diverse inventions, which led to even more innovations, which rapidly spread to other parts of the globe where differences in culture, resources, or simple intellectual talent could add to innovations further. Science and an educated populace were key players even early on in this feedback loop and the industrial revolution quickly morphed into the technological revolution – industry combined with science if you will. This dovetailing of industry and science began early in the industrial revolution when people like Sadi Carnot (1796-1832) and Rudolf Clausius (1882-1888) tried to understand how to make steam engines work more efficiently, and if it was even possible for *all* the energy put into a steam engine to be transformed into work. Their intellectual efforts in turn gave birth to a foundational area of physics, thermodynamics. As discussed earlier, later pioneers like Ludwig Boltzmann and the American physicist, Willard Gibbs (1839-1903) developed an even deeper understanding of thermodynamics and its core tenets like entropy. This led eventually to Claude Shannon, John von Neumann (1903-1957), Rolf Landauer, and other 20th century thinkers to finding the link between thermodynamics and information. Now, we have come full circle back to information theory.

Of course, to this day, the interplay between energy flows and informational flows continues to propel human social changes and complexity at an astounding rate – for both better and worse. On the side of "better," humanity has not seen a Malthusian crisis of population crashes via mass starvation or epidemics due to advancements like inexpensive crop fertilizers, clean water supply, and vaccines to name a few. Even the Spanish flu, the worst epidemic of the modern era killed "only" up to 3.3% of the population (http://www.history.com/topics/1918-

flu-pandemic) versus the black death which may have killed up to 33% of Europe's population in the 14th century (http://www.history.com/topics/black-death). However, it is also evident that our increasing population and social complexity, with its extraordinary demands on our planet's limited resources, comes at the cost of damaging another ancient, unique, invaluable, and incredibly complex system - the Earth's biosphere.

Information and Complexity – A Conclusion

The foregoing discussion is a brief introduction of why information is an inseparable, integral aspect of complexity. Of necessity given the space allowed, the review has been both superficial in depth, and incomplete in scope. Indeed, information science has made contributions to many disciplines from computer science, to economics, to sociology. Much more mathematics and other insights can also be offered to describe or predict various phenomena from the amount of information believed to reside on the surface of black holes, to how much information the brain is capable of storing. Complexity science also offers more profound insights and math for examining and predicting features of complex systems, and has even discovered other surprising sources of ontological indeterminism (Mitchell, 2009, p33). Quantum mechanics and thermodynamics are not the only disciplines to discover that the universe is ultimately statistical rather than deterministic – the "clockwork universe" was a mirage.

Information theory and complexity science will consequently be a rich fount from which big historians can better analyze and understand countless events, and processes that have occurred over time. Likewise, information and complexity scientists will find big history to be a rich source on which to apply their insights on this inherently rich and cohesive multi-disciplinary project. After all, even though the 20th century will be remembered in part as the time when relativity, quantum mechanics, and information theory were all discovered, it is still likely that our contemporary age will continue to be remembered *not* as "the "relativity period," or "the quantum era," but instead as "the information age."

Side bar: A brief overview of logarithms

If you are like me, it was decades since I had done any mathematics involving logarithms. Fortunately, basic logarithmic mathematics is relatively straight forward, and although not absolutely essential to understand the basic concepts behind both the second law of thermodynamics and information theory, it is quite helpful.

A logarithm is expressed in a "base" that is some number greater than 1. One of the most common logarithms (log for short) is expressed in base 10 and formally shown as $\log_{10}$. Many times, however, the subscript is left off and is simply shown as "log." The log of a number is what that number would be if 10 was increased by some exponent. For example $10^3 = 1000$, therefore, log 1000 = 3. $10^6 = 1{,}000{,}000$ and, therefore, the log of 1,000,000 is 6, and so on. The log of some number between 1 thousand and 1 million would similarly be between 3 and 6. A calculator can show you for example that log 5700 = 3.7559. In other words, $10^{3.7559} = 5{,}700$.

One of the obvious advantages of logs is that it makes it easier to express very large numbers. This feature is useful in thermodynamics where a vast number of microstates are possible for a system, or in information theory where a similarly large amount of data is involved. An especially importantly feature of logs for information theory is that if you combine the logs of information of two sources, the logs are additive rather than multiplicative. To illustrate this importance, imagine that you have two books of the same size that cover two entirely different topics.

If you combine the different number of possible messages from both books, represented as B1 and B2, you would have B1 x B2 = $B(1 + 2)^2$ possible informational content. However, your intuition tells you that you would not square the amount of information that you gain by reading two separate books, but instead it should be doubled at most. Logs solve this problem by being additive for the increase in informational content rather than multiplicative. In this example, using the rules of log: log (B1 x B2) = Log B1 + Log B2.

Other important log rules:

$Log_b(x^n) = n\ Log_b\ x$

$Log_b\ (x/y) = Log_b\ x - Log_b\ y$

$Log_b\ (1/x) = - Log_b\ x$

$Log_b\ 1 = 0$ (regardless of which base is used)

Knowing these rules is important if you decide to read some source on information theory or thermodynamics, because different authors will often use different appearing versions of the same equation (and sometimes with different letters to represent the same variable) – which can be confusing to say the least, e.g., most information science books use "H" to represent information content, while Chaisson's book *Cosmic Evolution*, uses "I.". It's also important to know that the log base used, whether it is 10, 2, "***e***," or some other value is arbitrary and doesn't fundamentally change the equation except for the value of an accompanying constant, often denoted as "k." (Note: "***e***" or "Euler's number" is an irrational number that mathematicians often use. When used as a log base, is called a "natural log" and often abbreviated as "ln.")

Because information theory's preferred numbering system is "binary," the log base used in information is typically "2." Therefore, because $2^1 = 2$, $2^2 = 4$, and so on, the log_2 of a number gives you the number of bits involved. For example, if you want to determine the minimum number of bits needed to communicate using only the upper case letters of the alphabet plus a space, you will need at least $log_2\ 27 = 4.75$ bits. Because you can't pragmatically have 0.75 of a bit to actually use in practice, you will need a minimum of 5 bits to communicate this way, e.g., a = 00001, b = 00010, and so on. ASCII is a code commonly used in computer programming and has 7 bits to represent all the symbols on a standard Western keyboard. 2^7 =128 possible bit combinations, which allows all the symbols (a-z, A-Z, 0-9, #,@, etc.) on the keyboard to be represented by its own unique binary code. Hence, in information theory and computer science, the log base is considered to be a "2" as a default and is frequently not indicated in that literature.

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Is Big History a Movement Culture?

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Abstract: This essay analyzes Big History as a movement, one that has been evolving from individuals and small groups of people working independently to a scholarly community and a set of institutions no longer dependent on founding individuals. The essay uses theoretical models to do so, notably movement cultures in politics and Thomas Kuhn's idea of paradigm shifts in science. It compares Big History to movement building in the early modern era, notably the "Republic of Letters" (i.e., Enlightenment and Scientific Revolution) and religious revivals. Finally, it compares Big History to related genres that explore the past on a large scale. The essay's goals are both empirical and reflexive, to help practitioners of Big History understand what their field is and, in doing so, consider what it should be.

The conversion narrative is an autobiographical genre familiar to scholars of religious history. The genre is characterized by stories of awakening, enlightenment, and wonder, of being lost and then now found, and setting on a new path, often with a mission. The story is a form of witness to others, in solidarity with others who have seen the light, and as inspiration for those who have not yet seen it. The road to awakening can be long and gradual or come in an instant, in a road to Damascus encounter. Such stories are essential to the coherence and growth of movements. Big Historians often tell loosely similar kinds of stories of their intellectual awakening in discovering Big History, setting them on new scholarly or teaching paths or new forms of activism. The IBHA *Newsletter*, now *Origins*, has regularly included such narratives.[1]

My own first encounter with Big History was through David Christian's book, *Maps of Time*, which I stumbled across in an Amazon search for another book related to world history, the algorithms of Amazon rather than an itinerant Big History evangelist telling me that I might be interested in the book.[2] I was. *Maps of Time* helped me to conceptualize with a new clarity my own loosely held ideas about how human history related to evolutionary history and how my own discipline of history might relate to disciplines that study the deep past. When the International Big History Association came to Grand Rapids in 2012 for its inaugural conference, I decided to explore Big History as a discipline, a community, and a growing set of institutions. I also started incorporating elements of Big History into my classes.

This essay explores whether the field of Big History, as a field of study, is a movement culture. The essay is meant to be both impartial, in exploring what Big History is, and reflexive, in spurring practitioners to reflect on what they are doing as

1 The idea for this essay goes back to hearing autobiography stories in presentations and information conversations at IBHA conferences in Grand Rapids in 2012 and at Dominican University in 2014 and reading autobiographical stories like this in the newsletter and *Origins*. I gave it as a paper at the IBHA conference in Amsterdam in 2016.

2 *Maps of Time: An Introduction to Big History* (Berkeley: University of California Press, 2004). There are itinerant Big History evangelists. An example is Michael Dowd, who has participated at Big History conferences. His website, The Great Story," describes him as "a Big History evangelist, evolutionary theologian, and bestselling author," http://thegreatstory.org/god-in-big-history.html (accessed 22 November 2017).

Big Historians and why. By movement culture, I mean evolution from individuals and small groups of people working independently or in loose conversation to a self-conscious community and a set of institutions no longer so dependent on founding individuals. The essay also uses Thomas Kuhn's idea of paradigm shifts and makes comparisons to political movements and early modern networks of letter writers. It explores how Big Historians tell stories, of humanity's place in the universe and of their discovery of Big History. Finally, it compares Big History to related genres that explore the past on a large scale. Big History has matured enough as a community and set of institutions where a diversity of goals and vision in the movement are leading to factions and even conflict, tensions familiar to intellectual movements that seek a secure, respected place in the academy and aspire to influence more widely in society.

Movement Cultures

Thomas Kuhn's "paradigm shift" explanation for scientific revolutions is best known for the epistemological questions it raises. "Kuhn argued that each scientific field is organized around an overarching, or paradigmatic, theory. In normal, everyday science the social networks and community experiences of scientists in laboratories and professional associations help reinforce the dominant paradigm. Sealed off in their enclaves, scientists routinely try to explain away any anomalies that their research might turn up. Only when forced by mounting evidence to confront these anomalies will some scientists . . . make a sudden mental shift which permits them to break with normal science."[3] In these revolutionary moments new models of science, such as Darwin's theory of natural selection, can win adherents. Science does not evolve as a result of steady accumulation of empirical data and ongoing refining of theoretical models, Kuhn argued. Normal science resists fundamental change, whether in methodology or metaphysics, and the institutions of science are designed to replicate existing approaches and hold off outlying methods and marginal theoretical perspectives—as was the case with natural selection and the big bang. As this summary suggests, part of a scientific revolution is conceptual, a new way of thinking.

Equally important, and more important for this paper, is the battle Kuhn described over institutions and the creation of new movements and institutions in revolutionary moments in science, as defenders of prevailing normal science battle with advocates of revolution science, and sometimes revolutionary science becomes the new normal. Scholarship in the history of science confirms this institutional component. For example, debates over natural selection in the nineteenth century intersected with conflict between gentlemen amateur scientists and scientists who professionalized their work in new research institutions and universities. The revolution was not only conceptual—older creation accounts versus evolutionary ones, or Lamarckian vs Darwinian forms of evolutionary theory—but over who scientists were, how they should be trained, and how and where they did their work.[4]

What sort of paradigm shift does Big History

3 Joyce Appleby, Lynn Hunt, and Margaret Jacob, *Telling the Truth About History* (New York: Norton, 1994), 164. For a short general introduction to Kuhn's thought, see Alexander Bird, "Thomas Kuhn", *The Stanford Encyclopedia of Philosophy* (Fall 2013 Edition), Edward N. Zalta (ed.), http://plato.stanford.edu/archives/fall2013/entries/thomas-kuhn/. For an overview of recent discussion in the history and philosophy of science, see John Zammito, *A Nice Derangement of Epistemes: Post-positivism in the Study of Science from Quine to Latour* (Chicago: University of Chicago, 2004). From Kuhn, of course, see *The Structure of* *Anniversary Edition* (Chicago: University of Chicago, 2012).

4 A useful, reader friendly overview of institutions of knowledge, including a chapter on the modern university and one on the laboratory, is Ian McNeely, with Lisa Wolverton, *Reinventing Knowledge: From Alexandria to the Internet* (New York: Norton, 2008). A useful biographical case study is Adrian Desmond, *Huxley: From Devil's Disciple to Evolution's High Priest* (New York: Basic Books, 1997). For the general history, see Peter J. Bowler and John Pickstone, eds., *The Cambridge History of Science*, Volume 6, Modern Life and Earth Sciences (Cambridge, UK: University of Cambridge Press, 2009).

represent, then? It is not a revolution in a specific scientific discipline, as described by Kuhn. It is a narrative and analytical synthesis of the work of today's "normal science" in disciplines across many fields, from the natural sciences to the social sciences and humanities. Big history's synthetic impulse is counter-cultural in an intellectual world dominated by disciplinary specialization and a social culture characterized by fracture.[5] But Kuhn's core idea is still valuable here. What is the appeal of big synthesis today, for some people, and why do disciplinary silos seem unsatisfying to them? Big History is an intellectual and cultural insurgency in its synthetic ambition and in seeking to influence not only academia, but also public discussion of issues related to science and society and elementary, middle, and high school curricula. The next section of the paper will explore these issues in more detail. This rest of this section briefly focuses on practical side of Kuhn's paradigm shift model: how new movements evolve institutionally.

One helpful model for thinking about such evolution is Lawrence Goodwyn's notion of a movement culture. A movement culture is not just an alternative way of thinking or living, different from the mainstream; it is oppositional. That is, it seeks to transform a received culture. Goodwyn pointed to "the sequential process of democratic movement-building, in the creation of new institutions ("movement forming"), new means to attract masses of people ("movement recruiting"), successful cultural formation ("movement educating"), and influence on society ("movement politicized").[6] The first three of these apply readily to Big History—in the IBHA itself, the Big History project, Chronozoom, and curriculum for schools, books for children, and popular documentary films.[7] Big History is not a political movement. Nonetheless, working toward a sustainable future is a motivation for many of its proponents, as advocates who have learned from Big History to envision humanity's evolving place on our planet in new ways, and as responsible citizens who have become determined to care for it.[8]

Two other historical analogies strike me as relevant, both from the early modern era. People rightly look to the print revolution to explain the impact of the Reformation, Scientific Revolution, evangelical revivals, and Enlightenment. Historians have shown that letters played a major role as well. Civil society first emerged in what historians sometimes refer to as the "Republic of Letters," as intellectuals spread word of new books and ideas in letters meant to be copied and to be read to groups in homes, salons, and scientific societies. Scholars have even mapped some these connections in digital

5 See Daniel T. Rodger's recent study, *Age of Fracture* (Cambridge, MA: Harvard University Press, 2011).

6 Lawrence Goodwyn, *The Populist Moment* (New York: Oxford University Press, 1978), xviii. Goodwyn used the concept to explain the rise of the Populists, an agrarian political movement in the American South and West in the late-nineteenth century. The concept also has been used to examine labor movements in that era. See William S. Solomon and Robert W. McChesney, eds., *Ruthless Criticism: New Perspectives in U.S. Communication History* (Minneapolis: University of Minnesota Press, 1993), particularly the chapters on working class politics and newspapers. Big Historians articulate a vision of science common in that same era, in which science offered a "comprehensive worldview," one that could replace "religious authorities" as the ground for ethical living and democratic citizenship and foster a Progressive future. See Andrew Jewett, *Science, Democracy, and the American University: From the Civil War to the Cold War* (Cambridge, UK: Cambridge University Press, 2012), 2.

7 Chronozoom's status in the future is uncertain, but the site remains accessible. http://www.chronozoom.com/ (accessed 22 November 2017). For the Big History Project, go to https://www.bighistoryproject.com/home (accessed 22 November 2017). The International Big History Association Website is https://bighistory.org/ (accessed 22 November 2017).

8 See, for example, David Gabbard, "Big History's Greatest Lesson? How to Find Humility in Our Commonality," *Origins* IV:4 (2014), 7-8. From the related field of ecological economics, see Robert Costanza, Lisa K. Graumlich, and Will Steffen, eds., *Sustainability or Collapse: An Integrated History and Future of People on Earth*, Dahlem Workshops Report (Cambridge, MA: MIT Press, 2007).

history projects.[9] Likewise, in the Great Awakenings of the eighteenth century, Protestant revivalists from Europe to the British Isles and North America spread word of religious renewal, reading each other's letters, publishing news of new awakenings, and spreading new theologies. Today the internet makes the creation of literal and virtual communities easier, locally and globally.[10] Websites such as Metanexus, The Great Story, Center for the Story of the Universe, and the Big History Project come to mind, as do groups on Facebook and videos on YouTube, Vimeo, and the TED website. As with the Republic of Letters and Great Awakening, Big History's networks include scholars, popularizers, and patrons reaching out to diverse audiences, from intellectuals, to children, to religious seekers.[11]

As movement cultures grow, they tend to both formalize and diversify, sometimes maintaining a "big tent" unity, albeit with tensions, sometimes falling into factions and boundary setting, institutionally and intellectually.[12] Such divisions often involve negotiating the boundary between elite and popular expressions of the movement. They also stem from significant intellectual and cultural differences or distinct goals, particularly tensions between strategic compromises with the received culture and oppositional radicalism.

Big History as a Movement Culture

The received culture addressed by Big History is a specialized, sub-divided, siloed, even "fractured" intellectual culture, characteristic of both academia and society at large today. The revolution promoted by Big History is a new way to integrate knowledge, a "great story" based on science that not only provides a scholarly synthesis across the disciplines, but also a "modern mythology" that can help people to understand their world and their place in the universe and motivate them to address global problems.

The mythic element in Big History is evident in the way individuals make it part of their own stories and vocations. "I had spent my entire career as a student and a teacher thinking of knowledge as needing to be carved up into bite sized, easily digestible and deliverable pieces," explained Tracy Sullivan in the IBHA *Newsletter* in 2012. "Big History has shown me the immense power of the interaction of knowledge across the largest scales and the broadest array of disciplines. Paradoxically, by defining this landscape of understanding in the largest possible frame Big History has led to me no longer feel overwhelmed and lost." This is what myth-histories do—provide narrative order to the fragmented pieces of the past, present, and future (whether empirically-based or fictional). "I am now inspired and excited to engage with a narrative and theoretical structure that is simple enough to guide my inquiry yet complex enough to allow for continued investigation, learning and discovery," Sullivan went on to say. "The beauty of this subtle balance between 'simplicity' and 'complexity' is that Big History becomes accessible to those at all levels of the educational spectrum from primary school through to academic

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9 For short introductions to the Republic of Letters, see Appleby et al, *Telling the Truth About History*, chapter 1; and McNeely, *Reinventing Knowledge*, chapter 4. See a project at Stanford University, "Mapping the Republic of Letters." http://republicofletters.stanford.edu/index.html (accessed 7 May 2016); the case study on Benjamin Franklin shows transatlantic connections: http://republicofletters.stanford.edu/casestudies/franklin.html (accessed 7 May 2016).

10 On how promoters of religious revivals in the same era created a transatlantic movement, see Susan O'Brien, "A Transatlantic Community of Saints: The Great Awakening and the First Evangelical Network, 1735-1755," American Historical Review 91:4 (October 1986), 811-832; Jennifer Snead, "Print, Predestination, and the Public Square: Transatlantic Evangelical Periodicals, 140-1745," EAL 45 (2010), 93-118; and, Frank Lambert, Inventing the "Great Awakening" (Princeton, NJ: Princeton University Press, 2001).

11 On Big History's patron, see Andrew Ross Sorkin, "So Bill Gates Has This Idea for a History Class," *New York Times Magazine*, The Education Issue, 5 September 2014; http://www.nytimes.com/2014/09/07/magazine/so-bill-gates-has-this-idea-for-a-history-class.html (accessed 14 May 2016).

12 For an overview of scholarship on boundaries and the social sciences, see "Michèle Lamont and Virág Molnár, "The Study of Boundaries in the Social Sciences," *Annual Review of Sociology* 28 (2002) 167-95.

researchers."[13] Sullivan's short autobiographical essay effectively summarized how Big History is both a narrative synthesis, with mythic resonances, and an interdisciplinary scholarly field, perhaps best compared to "area studies" programs, its "area" encompassing the entire planet and universe.

Sullivan also explained how the institutions associated with Big History connected her personal transformation to a larger community. "During the IBHA conference I was struck by how often the words 'awe' and 'wonder' were used. Not about subject matter alone, but how Big History has a transformative power on the way people experience and understand the world and environments around them," Sullivan said. She wants this for her students. "Having a sense of being part of something far greater than oneself, and an understanding of what an astoundingly beautiful, fragile and volatile 'something' that is, changes the way we perceive ourselves and our environments. It has certainly done this for me. If I tend to sound like a Big History evangelist I am proud to say that I am."[14] Not all Big Historians use such religious language, though it is noteworthy how often religious metaphors and allusions crop up in Big History conversations, even among avowedly atheist or agnostic scholars. The key point here is how consistently—in panels and informal conversations at IBHA conferences, in essays in the IBHA newsletter or *Origins*, or other online venues—autobiography is part of participating in Big History.[15] I generally do not observe this pattern at other scholarly associations and meetings in which I participate regularly. Exceptions in my experience include panel sessions that discuss the intersection of personal religious commitments and studying religious history. Autobiographical reflection also is common in the context of African American studies, women's studies, and LGBTQ+ scholarship.[16] The common denominator in these examples seems to be (1) new, still marginal fields of scholarship securing their place in academia; and (2) fields of study with close ties to social and political movements. In these cases, we can see how the personal is political, to use a familiar feminist trope, and how the intellectual is personal. We also can see negotiation of boundaries, as fields of study become more mainstream.

Boundary conversations took place at the IBHA conference in California in 2014 and more have followed in *Origins* since then. Four scholars published a letter entitled "Is the IBHA at a Crossroads?" They addressed concerns about speakers at some panels "using Big History as a platform to promote personal 'spiritual' agendas," where the lines between "science" and "interpretation," and "facts" and attributed "meaning," were transgressed. They also noted the "screening of *Journey of the Universe*," a

13 As the paragraph suggests, I use the term mythic here not as a measure of good or bad history (or science), but a story told to shape an identity, whether of a person or a group. Tracy Sullivan, "Teaching Big History," *International Big History Association Member's Newsletter* II:8 (November 2012), 6-7.

14 Sullivan, "Teaching Big History," 7.

15 For further examples, see Kenneth Gilbert, "Across the Shores of Big History: Footprints in the Sands of Time," is a good example; see *International Big History Association Member's Newsletter* II:8 (November 2012), 1-6; and Gabbard, "Big History's Greatest Lesson?"

16 In general, in historical scholarship, see chapters 13-16 in Peter Novick, *That Noble Dream: The 'Objectivity Question' and the American Historical Profession* (New York: Cambridge University Press, 1988)). A useful study of issues related to gender and sexuality is Jo Reger, Daniel J. Meyers, and Rachel L. Einwohner, eds., *Identity Work in Social Movements* (Identity Work in Social Movements (Minneapolis: University of Minnesota Press, 2008). On African American history, see V.P. Franklin, "The Power to Define: African American Scholars, Activism, and Social Change, 1916–2015," *The Journal of African American History* 100:1 (2015), 1-25. Note also Charles Tilly, in "Political Identities in Changing Polities," *Social Research* 70:2 (2003), 605-620; and *Stories, Identities, and Political Change* (Lanham, MD: Rowan and Littlefield, 2002). On personal history and religious history, see essays by Anthea Butler, Richard Bushman, Brad Gregory, Mark Noll, Paul Kerry, and Donald Yerxa, all in *Fides et Historia*, 43:2 (2011), 1-41. Note also Nick Salvatore, ed., *Faith and the Historian: Catholic Perspectives* (Urbana: University of Illinois Press, 2007); and Donald J. D'Elia and Patrick Foley, eds., *The Catholic as Historian* (Naples, Fla.: Sapientia Press of Ave Maria University, 2006)

documentary film by Brian Swimme: "For some, it expressed the anthropic notion that the universe has a larger purpose; and tells a 'story.' For others, the narrative seemed to express a 'naive, romantic view' with a 'spiritual' interpretation." The discussion that followed revealed a "split" between "scientists" and "spiritualists."[17] One might quibble about the details of this account. Scientists can also be spiritualists, after all. And the line between "facts" and "interpretation" is blurry in science (as in other fields), according to the consensus of scholars in the history, sociology, and philosophy of science.[18] But the letter writers were quite right in what is at stake. Should the IBHA pursue an inclusive or exclusive path? "An inclusive approach would offer a wide variety of insights and the creativity necessary for a young organization and discipline to grow," they noted. "The downside, however, is that the lack of scholarly rigor is likely to dissuade scientific researchers from participating and would undermine the credibility of the association *and* the discipline. Exclusion, on the other hand, implies the risk of creating an isolated, homogenous, and a somewhat detached research environment that may suffer from confirmation bias and inbred development." The authors suggested that the IBHA offer two tracks, one with a rigorous peer-reviewed process for academic papers and one for spiritual "interpretation."[19] This dual approach leaves room for a big tent, though it clearly sees the core of Big History as scientific and could be viewed as trying to quarantine the spiritual track so that those uninterested in it can easily avoid it.

17 Laura Rahm, Steve Sisney, Gus Lyn-Piluso, and J. Daniel May, "Is the IBHA at a Crossroads?" *Origins* IV:10 (2014), 20-21.

18 I explored this issue in "Myth, Meaning and Scientific Method in Big History," *Origins* V:12 (December 2015), 3-12.

19 Rahm, Sisney, Lyn-Piluso, and May, "Is the IBHA at a Crossroads?" 20-21. Fred Spier implicitly affirmed these concerns, in a response, noting that this issue has been discussed since the 2012 IBHA conference; see Spier, "Reply to: Is the IBHA at a Crossroads?" Origins IV:10 (2014), 22 The process of proposing academic papers/panels for the 2016 conference followed the suggestions of the letter writers, at least loosely.

Imogene Drummond pushed in the opposite direction in "A Visionary, Transformative, Diverse IBHA," published in the same issue. She opposed the creation of two Big History organizations and urged the IBHA to expand its "identity or mission statement to include three core concepts: Macro, Transformative, Visionary." Macro approaches to Big History, in her conception, are about cooperative cultural thinking that will allow humanity to flourish. Transformative approaches focus on education and popularization outside scholarly circles, in school curricula and the arts. The Visionary emphasis is about new concepts and ideas to link knowledge across disciplines. All these are equally and rightfully part of Big History, she argues.[20]

The "scientific," metaphysical, and moral cannot easily be separated, the letter writers and Drummond seem to agree. The question is how to have productive conversations about them. Big History does not require a monolithic worldview and much of its work is empirical.[21] Nevertheless, all Big History work involves non-empirical worldview assumptions, including the scholarship of Big Historian scholars who work in the sciences. Philosophical, aesthetic, and even theological conceptions are embedded in core big history concepts (e.g., complexity and emergence).[22] The "mapping" that Big Historians

20 Imogene Drummond, "A Visionary, Transformative, Diverse IBHA," *Origins* IV:10 (2014): 23-25. A good example of the kind of work that Drummond proposed is Joseph Voros, "The Past, Present and the Future: A Q&A with Futurist and Academic Member of the Big History Institute, Macquarie University," *Origins* 6:4 (2016): 3-6. Voros makes the case for a variety of public policies that will promote the ongoing sustainability of human progress. He also speculates, in the borderland between science and science fiction, about what might lie beyond our planet: "fellowships . . . with other intelligences and civilisations," "in futures that may yet come."

21 Fred Spier addressed the question of worldview in "Big History is Not an All-Encompassing World View," *Origins* VI:2 (2016): 3-5.

22 In "The Meaning of Big History, Philosophically Speaking," Cynthia Stokes Brown describes Big History involving methodological materialism, but not philosophical materialism; see *Origins* VI:1 (2016): 7-13. She also notes "that hidden between these lines are many layers of

do is shaped by conceptions that entail "meaning."[23] There is no neutral empirical base of science on which meaning is imposed. The two shape each other in subtle ways. David Christian has argued that Big History is a scientific version of "universal history," a tradition that in the West that dates back to the ancient Greeks, Romans, Hebrews, and to classical, medieval, and early modern Christians.[24] Allan Megill, Nasser Zakariya, Ian Hesketh, Peter Harrison, and others have argued that the narrative and science of Big History remain indebted to these deeply-rooted philosophical and theological traditions.[25] In other words, Big History has its own deep history. Such deep roots characterize all academic disciplines. What is unusual about Big History is that these issues are discussed explicitly, rather than left suppressed. Big History's emphasis on synthesis and a singular narrative that "maps" across time from the Big Bang to the present brings such matters to the fore, especially in popular expressions of it. The question is not whether Big Historians and IBHA should avoid talking about boundary issues or include them as an essential component of doing Big History. We have been doing the latter since 2014 at least. The questions are: (1) How to do it and to what end? (2) Will Big History as a field of study and intellectual and cultural movement hold together in the process or will it fragment?

Comparisons

Some wisdom for how the IBHA and Big Historians should address boundary issues can be found in comparing Big History to related fields of study. The closest of these fields are deep history, evolutionary history, and ecological economics. All of these are multi-disciplinary, like Big History, though all limit their scale to the period since the emergence of early humans. Deep history integrates the study of early humans ("prehistory") and post-Neolithic history, areas of work normally done separately, to see how they can illuminate each other—in areas such as family life, community formation, food cultures, religious expression, and communication. Evolutionary history examines the co-evolution of humans (and human societies) and other species.[26] Ecological economics analyzes

philosophical thought" (7).

23 I am here riffing on David Christian's title, "From Mapping to Meaning," in Alan Culpepper and Jan van der Watt, eds., *Creation Stories in Dialogue: The Bible, Science, and Folk Traditions* (Leiden, Boston and Tokyo: Brill, 2015). My point is not an intellectual "Gotcha!" Rather, it is to point to common ground in the reflections of those who practice Big History and those who analyze it critically as historiographers.

24 "The Return of Universal History," *History and Theory*, Theme Issue 49 (December 2010), 6-27. For a precursor of sorts, by the longtime dean of world history, William H. McNeill, see "The Changing Shape of World History," *History and Theory*, 34:2 Theme Issue 34: World Historians and Their Critics (May, 1995), pp. 8-26. Like Christian, McNeill noted the mythic power of world history (coining the term "mythhistory" decades earlier) and its relevance given the crises of the late twentieth century.

25 Megill, "Big History' Old and New: Presuppositions, Limits, Alternatives," *Journal of the Philosophy of History* 9:2 (2015): 306-326; Nasser Zakariya, "Making Knowledge Whole: Genres of Synthesis and Grammars of Ignorance," *Historical Studies in the Natural Sciences* 42:5 (November 2012): 432-47; Ian Hesketh, "The Story of Big History," *History of the Present*, 4:2 (Fall 2014): 171-202; Thomas M. Lessi, "Science and the Sacred Cosmos: The Ideological Rhetoric of Carl Sagan," *Quarterly Journal of Speech* 71:2 (1985): 175-187; Hesketh, "The Recurrence of the Evolutionary Epic," *Journal of the Philosophy of History* 9:2 (2015): 196-219. Zakariya, *Towards a Final Story: Time, Myth and the Origins of the Universe* (PhD dissertation: Harvard University, 2010) and Alex Moddejonge, *The Biggest Story Ever Told: On the Historiographic Origins of Big History* (MA thesis: California State University San Marcos, 2012) and Peter Harrison, "Sacred History, Evolutionary History, and the Status of Human Beings," a lecture at the University of Queensland, Institute for Advanced Studies in the Humanities, 7 April 2016. The podcasts of the lectures are here (scroll down to April 7): https://iash.uq.edu.au/node/746 (accessed 8 May 2016).

26 For a review of work in these areas, see Nasser Zakariya, "Is History Still a Fraud?" *Historical Studies in the Natural Sciences* 43.5 (2013): 631–641. In addition to several works of Big History, Zakariya reviews Edmund Russell, *Evolutionary History: Uniting History and Biology to Understand Life on Earth* (Cambridge: Cambridge University Press, 2011); and, Daniel Lord Smail, *On Deep History and the Brain* (Berkeley: University of California Press, 2001). Note also Andrew Shyrock and Daniel Lord

the co-evolution of human political economies and natural ecosystems, with an eye to sustainability. Exploring the histories of ecological collapse and the recovery of civilizations, ecological economics can help us understand and address twenty-first century problems of sustainability. Ecological economics straddles the boundary between academic institutions and think tanks, and this field is much more "applied" in its scholarly goals than Big History.[27] Compared to Big History, these fields are strictly scholarly and technical. They do not aspire to a scientific universal history, to reshape high school and university curricula, or to serve as a "modern mythology." Because these fields are narrower, they do not have the boundary issues addressed in this essay, around morals, meaning, philosophy, theology, and spirituality. Nor do they have the popular influence that Big History has achieved in recent years. They are not movement cultures seeking wider public influence or to transform elementary, middle, and high school curricula.

In Big History's aspiration to shape school curricula, especially through the Big History Project, a useful comparison is survey courses in Western Civilization and world history in high school, colleges, and universities. In all three cases, an essential goal has been to shape citizens, in the interest of shared identities and the knowledge, values, and thinking skills needed to be thoughtful citizens of their nations and the world. Simplifying, Western Civilization courses emerged in North America in 1920s and 1930s, in the wake of World War I and the crises that led to World War II, as educators asserted the need for students to understand their place not just in their nation but the larger world. That larger world was defined by Western Europe, the presumed "mainstream" of human progress in history. In the 1970s, 1980s, and 1990s, civil rights movements, immigration to North America and Europe from the Global South, and globalization led to world history courses replacing Western Civilization courses. Educators recognized that "the West" was only part of the larger world, not its mainstream, and that migration and globalization were transforming North America and Western Europe.[28] Big History has done the same in the past decade or so, as issues such nuclear war, global sustainability, and climate change—the "Anthropocene"—indicate that world history needs to be expanded by placing the history of our species in the context of planetary and cosmic history.[29]

In all three cases, boundary issues have been central. How should "scholars" in universities work with "teachers" in middle and high schools? How do ideals of objectivity and studying the past for its own sake fit with "civilizational" goals

Smail, eds., *Deep History: The Architecture of Past and Present* (Berkeley: University of California Press, 2012).

27 For an example of work in this area, see Costanza, Graumlich, and Steffen, eds., *Sustainability or Collapse*.

28 On these fields, see Gilbert Allardyce, "Toward World History: American Historians and the Coming of the World History Course," *Journal of World History* 1:1 (spring 1990), 23–77; Lawrence Levine, *The Opening of the American Mind* (Boston: Beacon, 1996); Gary B. Nash et al, *History on Trial: Culture Wars and the Teaching of the Past* (New York: Vintage, 2000); Patrick Manning, *Navigating World History: Historians Create a Global Past* (New York: Palgrave, 2003); Lynn Hunt, *Writing History in the Global Era* (New York: Norton, 2015); and, Paul Costello, *World Historians and Their Goals: Twentieth Century Answers to Modernism* (DeKalb, IL: Northern Illinois Press, 1994). See also chapters 3 and 4 of Appleby et al, *Telling the Truth About History*.

29 The "Anthropocene" is the proposed name for a new geological era, beginning in the late eighteenth century, defined by the impact of humanity and our modern industrial civilization, identifiable in everything from radiation in soils around the globe to mass extinctions of plant and animal species, pollution, etc., all of which will leave a mark in the geological stratum of the planet that geologists can identify. On this question, see Joseph Stromberg, "What is the Anthropocene and Are We in It?" *Smithsonian Magazine*, January 2013, http://www.smithsonianmag.com/science-nature/what-is-the-anthropocene-and-are-we-in-it-164801414/?no-ist (accessed 5/14/2016). For an essay that makes the case, see Will Steffen et al., "The Anthropocene: conceptual and historical perspectives," *Philosophical Transactions of the Royal Society* A 369 (2011): 842–67. On the Anthropocene and historiography, see Dipesh Chakrabarty, "The Climate of History: Four Theses," *Critical Inquiry* 35:2 (Winter 2009): 197–222. The essay has since been published in a variety of venues online. See, for example, http://www.sciy.org/?p=3416 (accessed 4/28/2016).

of shaping citizens, values, and identities? How to take sophisticated technical scholarship and make its accessible for young readers and popular consumption? How should scholars work with citizens and officials on local and state boards that make decisions about curriculum? National and state standards for U.S. and world history both have been controversial for the past three decades. Ties between the scholarly organizations and teachers grew in the 1920s and 1930s and declined in the post-World War II era. Teachers continue to have a secondary place in major organizations such as the American Historical Association, though the AHA has had more panels on pedagogy in the past decade. Perhaps significantly, the World History Association is most like the IBHA in putting a significant emphasis on pedagogy and making a place for teachers. By taking on a planetary and cosmic scales of history, questions about meaning and worldview are inevitable for Big History, as questions of citizenship and identity have been in national, Western Civilization, and world history curricula.[30] If the IBHA as an organization considers school curriculum and influence on public life as part of its mandate, then boundary issues of the sort addressed in this essay are an essential part of the project.

Finally, all of these comparisons highlight another issue: What makes Big History distinctive? What is it at root? A methodology? A narrative that incorporates work from the many disciplines it incorporates? Whatever else it involves, Big History is a narrative and necessarily so. General laws and theories are inadequate (incomplete) to the task of explaining the past. Contingent events (not reducible to natural laws and general patterns) play a central role in biological evolution and human history. This includes natural contingencies, such as the mass extinctions 66 million years ago that led to the decline of dinosaurs and the emergence of mammals as a dominant class of species. It also includes cultural contingencies, such as the human harnessing of fossil fuels that led to the Anthropocene and to humanity playing a driving force in the planet's evolution.[31] Narration is essential for explanation of specific occurrences and non-replicable instances of cause and effect, as opposed to recurring types that can be modeled and predicted. These narratives are explanatory, not merely descriptive. Like scientific theories they create intellectual order. Narratives "grasp together" causes and effects and series of events into larger wholes, as in the American Revolution, Industrial Revolution, or Anthropocene.[32] General laws and narratives explain different kinds of things and neither alone is adequate for Big History. My own view is that Big History does not just involve narrative, and necessarily so, but that it is primarily a narrative. Theoretical categories such as complexity, bottlenecks, and thresholds are cyclical narrative markers, as forms of explanation, more than markers of natural laws. To say this is not to identify a weakness in Big History, but to point to its nature.

Here is where Big History can make significant contributions to the humanities and the sciences:

30 From world history, see Ross E Dunn et al, eds., *The New World History: A Field Guide for Teachers and Researchers* (Berkeley: University of California Press, 2016; note also a previous edition in 1999). Some of these issues are addressed for Big History in Richard B. Simon et al, eds., *Teaching Big History* (Berkeley: University of California Press, 2014).

31 For a practical introduction to this theme, see Esther M. van Dijk and Ulrich Kattmann, "Teaching Evolution with Historical Narratives," *Evolution: Education and Outreach* 2:3 (2009), 479-489.

32 J. David Velleman, "Narrative Explanation," *The Philosophical Review* 112:1 (January 2003): 8. A valuable exercise in showing how narratives explain is William Cronon, "A Place for Stories: Nature, History, and Narrative," *Journal of American History* 78:4 (March 1992), 1347-1376. For a useful introduction to issues related to narrative and explanation, see Geoffrey Roberts, ed., *The History and Narrative Reader* (New York, Routledge, 2001). A classic essay is Louis O. Mink, "Narrative form as a Cognitive Instrument," in Robert H. Canary and Henry Kozicki, eds., *The Writing of History: Literary Form and Historical Understanding* (Madison, WI: University of Wisconsin Press, 1978). Finally, note Robert F. Berkhofer, Jr., *Beyond the Great Story: History as Text and Discourse* (Cambridge, MA: Harvard University Press, 1997). On the Anthropocene, see Kelly Power, "Nature or Culture? The Anthropocene as Social Narrative," *Inquiries Journal* 9:5 (2017), http://www.inquiriesjournal.com/a?id=1643

highlighting the role of narrative in science. This role is not simply a matter of telling a story about work done in the sciences; narrative is part of the work of doing science, particularly evolutionary science. One of the boundary issues in Big History has been whether Big History is a "science" or "storytelling," some members of the IBHA noting that storytelling is not respected in their field of study. It is "mere" storytelling, the implication is, as opposed to real explanation, which involves universal laws and prediction of cause and effect.[33] One of the roles big history can play—along with evolutionary history, deep history, and ecological economics—is to help scientists see the explanatory role of narrative in their work and to make historians more comfortable with the role of science and its theoretical models in their work.[34]

Conclusions

Is Big History a movement culture? This question can be answered both objectively and prescriptively. In my judgment, empirically, Big History acts like a movement culture. Its synthetic, "modern mythology" impulse has been counter-cultural in an intellectual world dominated by disciplinary specialization, and it is seeking to transform not just the work of scholars but school curricula and popular intellectual culture. But this movement culture quality is in tension with Big Historians trying to fit into the frameworks of normal disciplinary science.

What should Big History be? Big History is most likely to have a significant intellectual impact if it embraces its "big tent" nature as an integrative narrative of universal history and finds equitable, intellectually accountable ways to manage the diverse impulses that its supporters bring to the IBHA. Its intellectual power rests precisely in the way its scope entails worldview questions, brings together academic and non-academic participants, pursues academic and non-academic goals, and puts in conversation modes of explanation from the sciences and humanities. Without the very things that have caused discomfort and tension at its conferences, and lead to creative, invigorating conversations in *Origins*, Big History is likely to be no more than a small academic voice among many other large-scale approaches to the past, perhaps the smallest among them, as deep history and ecological economics are narrower in their academic scope and fit the disciplinary specialization that characterizes mainstream academic work. That is to say, other "big" approaches to the past are less intellectually unruly and less interesting, precisely because they mostly involve scholars talking to themselves, and a narrow range of scholars at that. Only Big History has the narrative audacity to shape school, college, and university curriculum in a broad way.

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33 On science, narrative, and explanation, see, for example, Richard Johnson Sheehan and Scott Rode, "On Scientific Narrative: Stories of Light by Newton and Einstein," *Journal of Business and Technical Communication* 13:3 (July 1999): 336-58. They argue "that scientific discourse, like all narratives, describes what happened and what it meant. Indeed, scientific texts are almost always accounts of scientists' experiences in reality" (336).

34 An example is William Reddy, *The Navigation of Feeling: A Framework for the History of Emotions* (New York: Cambridge University Press, 2001). Reddy weaves together research from psychology, anthropology and cultural history. His work is not big history, despite its methodological diversity and breadth, but it exemplifies how putting the sciences, social sciences, and humanities in conversation can work.

The Glass Universe:
How the Ladies of the Harvard Observatory Took the Measure of the Stars
by Dava Sobel

New York, Penguin Books, 2017 332 pages $30.00 (hardcover)

Reviewed by David Chuss
Department of Physics, Villanova University

In her prior works, *Longitude and Galileo's Daughter*, Dava Sobel has established a narrative style in which she skillfully weaves tales of major scientific breakthroughs with the human stories and the historical context in which they occurred. This is especially true for her latest work, The Glass Universe, in which she details the stunning contributions of women to the development of modern astronomy.

In *The Glass Universe*, Sobel chronicles the storied Harvard Observatory from its early days in the late nineteenth century under the directorship of Edward Pickering. During this period, photography was starting to play a central role in astronomy, enabling a precise and permanent record of the heavens to be captured for the first time. This, along with the advent of stellar spectroscopy, a technique for measuring the distribution of colors present in starlight, revolutionized astronomy into its modern incarnation as a multi-tooled science capable of probing beyond the phenomenology of the heavens to a more comprehensive physical understanding.

The title of the book refers to the approximately 500,000 glass plates that contain the photographs and spectra of the sky observed by the telescopes of the Harvard Observatory from 1885 to 1992. These plates, still in use today, provide a symbol for the historical advancement of astrophysics over this century. From the perspective of the Harvard Observatory, Sobel elucidates the development of the modern field of astronomy from a cultural standpoint. The creation of modern institutions that are central to the field, such as the American Astronomical Society and The Astrophysical Journal, are woven into the narrative, connecting these events and people to the modern astronomical community. The role of the Harvard Observatory as a leader in the global astronomical community is also explored, as it evolved into its current incarnation, the Harvard-Smithsonian Center for Astrophysics.

The glass plates double as a metaphor for the central theme of the book, which is the struggle of the women of Harvard Observatory to be afforded the opportunity to contribute to this revolution to which they eventually would become an essential part. The narrative begins with Anna Palmer Draper, widow of astronomer Dr. Henry Draper, funding Pickering's efforts in memory of her late husband. Key to this effort were a group of women that were hired by Pickering as "computers" to analyze the early plates and to perform the tedious measurements and calculations necessary to extract quantitative information from these observations. As time progressed, many of these women, through perseverance, intellectual creativity, and passion, made revolutionary contributions to astronomy and earned the respect of their male counterparts.

Sobel's book provides important context for the scientific theories and methods taught in our classrooms and utilized in our laboratories. To appreciate the current state of astronomical knowledge, it is essential to understand this human struggle through which it was obtained. Without Henrietta Leavitt's discovery of the period-luminosity law for Cepheid variable stars, Edwin Hubble could not have utilized this cosmic ruler to determine that our universe is expanding. Likewise, Annie Jump Canon's system of classification of stars by their spectra provided a key tool that is still utilized by modern astronomers. The revolutionary understanding of the dynamics of stars, brought about by Cecelia Payne-Gaposchkin's clever insights, connected contemporary concepts in physics with observations of stellar spectra for the first time. These contributions serve as foundations of modern astrophysics.

The Glass Universe serves as an essential and fitting tribute to these undeservedly lesser-known pioneers of astronomy. Sobel's book provides a key part of a wider contemporary effort to right this oversight by providing the long overdue recognition that these great astronomers deserve. Perhaps when future generations of astronomers learn their craft, the names Cannon, Leavitt, and Payne-Gaposchkin will be introduced as equals to those of Russell, Hubble, and Eddington.

The Patterning Instinct: A Cultural History of Humanity's Search for Meaning

by Jeremy Lent

Amherst, NY: Prometheus Books, 2017. 569 pp. $17.68 (hardcover)

Reviewed by David Blanks
Arkansas Tech University

Jeremy Lent dedicates his new study of mind, myth and meaning "to future generations." His hope is that if we work together to change the "root metaphors" through which we view the world, then perhaps we can divert our (now global) civilization from the destructive trajectory that our old root metaphors have put it on. Arguing that culture changes history, and history changes culture, he calls his approach "cognitive history" which, as his preceptor, physicist and systems-thinking guru Fritjof Capra writes in the foreword, indicates that he "traces the human search for meaning through the lens of modern cognitive science, a rich interdisciplinary field that transcends the traditional frameworks of biology, psychology, and epistemology" (p. 14).

Thus (for the most part) Lent analyzes history with reference to the cognitive structures of the human mind. Drawing heavily upon systems theory, he charts the rise of complexity in the brain, in hunter-gatherer societies, and in the earliest agricultural communities, then goes through the emergence of diverse cultural metaphors in the Axial Age as a means of explaining the rise of Europe and how in the modern world we came to "consume the earth." If we want to understand the world today, the argument goes, then how the mind works matters, and how culture works, matters. Not all change can be reduced to material causes.

At first glance then this looks pretty good: it's interdisciplinary, scientifically-based, analyzes long sweeps of human history on a global scale, advocates social and environmental justice. It's a sort of corrective to the reductionist view of history. Not only is there a causative flow from environment to cognition but there is a reciprocal causative flow in the other direction, a perpetual, bidirectional feedback loop. Purely materialist approaches to historical change often miss this.

But the devil is in the details, as they say, and *The Patterning Instinct*, which itself is a whole greater than its parts, is filled with details about how the brain works, how patterns of thought arise, how these shared symbols (language, art, religion, science) give rise to cultural metaphors such as "Nature as Machine" and "Conquering Nature," and how these worldviews in turn lead to historical change. However, different cultures have different metaphors, and it is *our* culture, according to Lent, western (now global) culture, which is largely to blame for the damaging ways in which our root metaphors have manifested themselves on the planet.

Well perhaps we might be okay with that notion too; except that, when you examine the details, and think deeply about the implications of the culture => metaphor => values => actions model, specifically in regards to our discipline, it suggests that, contrary to its best intentions, the underlying cultural metaphors that support much of big history turn out to be the very same cognitive frameworks that have put us on this dangerous social and environmental path to begin with.

"As the book unfolds," Lent writes, "it reveals an underlying pattern to Western cognition that is responsible for its Scientific and Industrial Revolutions—as well as its devastating destruction of indigenous cultures around the world and our current global rush toward possible catastrophe. In this respect, the book shares much with the postmodern critique of Western civilization, recognizing those capitalized universal abstractions such as Reason, Progress, and Truth to be culture-specific constructions. In fact, a significant portion of the book is devoted to tracing how these patterns of thought first arose and then infused themselves so deeply into the Western mind-set as to become virtually invisible to those who use them" (p. 19). So whether we are persuaded by the "cognitive history" model or not, this is still something we are going to have to grapple with—and for this reason alone this book is worth reading.

Abstractions such as Reason, Progress and Truth, Lent argues, are not universal but culturally specific. These are the root metaphors upon which big history metaphors such as arrow of time, emergence, complexity, thresholds, and Goldilocks conditions rest, which creates something of a conundrum: Whereas big history wants global citizens to think *more* scientifically in order to guide the planet to a more salutary future, Lent feels that this is misguided. He wants us to reevaluate our values and to shift our cultural metaphors away from Christian and Scientific Revolution ones such as "Dominion Over Nature" and "Nature As Machine" toward eastern ones such as "Nature As Giving Parent" and "Reverent Guests Of Nature." There is nothing wrong with science—the work under review is scientifically-based—, but we cannot get at everything we want to know though science, Lent says, and therefore we will need room for philosophy too, and some of the more speculative scientific methods, and for art and psychology, and also for intuition.

Now in my estimation, "trying to introduce a new vision of the past" by weaving "many disciplines of human knowledge together into a single, seamless narrative" to see "whether the inhabitants of planet Earth will be able to cooperate in achieving the goal of reaching a more or less sustainable future in reasonable harmony" makes *The Patterning Instinct* a work of big history in the same manner, say, as Robert Bellah's *Religion In Human Evolution* (2011).[1] But some big historians won't see it this way.

And the author does not see it this way. (I asked him.) In fact Lent does not mention big history in this book at all, not even an oblique reference. He does not see it as a work of big history, he said, first, because he does not begin with the big bang and cosmic evolution but with an archaeology of the mind and the emergence of symbolic thought. Second, the author does not see his primary audience as students or academics but rather as educated laypersons perhaps with a social activist bent who, as he puts it, are caught between the incompatible worldviews of monotheism and scientific reductionism: people who "seek alternative explanations for meaning in their lives, which are frequently dismissed by science as incoherent" (p. 271). Lent offers as an alternative the Neo-Confucian tradition which, he says, "provides a coherent framework for systems-based interpretations of age-old Western philosophical issues such as how mind arises from the brain, what the basis of ethics and morality is, and how to live harmoniously and sustainably in the natural world" (p. 272).

At which juncture many readers of this journal will agree with Mr. Lent and say, no, this is not a work of big history, because it moves beyond explanations that are based upon the best available empirical evidence and an agreed-upon method of scientific reasoning narrowly construed. But this is just my point. It does not appear to me that the genie of big history is ever going to be stuffed back into that culturally-specific bottle, and now that it's out

1 David Christian, Cynthia Stokes Brown, Craig Benjamin, *Big History: Between Nothing and Everything* (McGraw Hill: New York, 2014), 2; Cynthia Stokes Brown, *Big History: From the Big Bang to the Present* (The New Press: New York, 2007), xi; 2; Fred Spier, *Big History and the Future of Humanity* (Wiley-Blackwell: Chichester, West Sussex, UK:, 2010), 203.

in the world, for every self-proclaimed big historian who has just placed this book back on the shelf and gone off in search of something by Richard Dawkins, there is another self-proclaimed big historian happily heading towards the check-out line.[2]

Let's be honest with ourselves. Big history is *not* methodologically or ideologically or even pedagogically unified. There exists a wide range of approaches from the "scientistic" (and I choose this term carefully) to the "mystic." Big history is still very much a contested discourse. One of the unanticipated benefits of this book is that it holds a mirror up to our discipline and forces those of us who choose to engage with it to reexamine our assumptions about what it is that we are trying to accomplish and how we are going about it.

Mr. Lent has chosen the venerable Prometheus Books (partnered with Random House since 2013) as publisher, and this hardcover edition it is being made available at a price that future generations will be able to afford, which fits well with Prometheus' philosophy as an "advocacy press" that seeks "to cultivate reason, science, humanistic values, and free inquiry in all areas of human interest." Neither a commercial press aiming to turn a profit, nor a university press that looks solely at scholarly appeal, Prometheus asks primarily whether a book "is meaningful to and readable by the general educated public." This one certainly meets that criterion while at the same time remaining challenging and serious of purpose.[3]

Where I take issue with *The Patterning Instinct* is in its characterization of the outcomes of the Axial Age and the subsequent unfolding of modernity. Many historians might find that the narrative is not nuanced enough—and too one-sided ideologically. Not that there is anything wrong with declaring your ideology up front: better that than pretending you don't have one. It's just that here in the thick of things, after a stimulating reflection on language, symbolic thought, what it means to become human, and the cultural metaphors produced by the earliest societies, the author veers off into a potted history of the differences among ancient civilizations and the rise of the West that boils down to a summative evaluation of Greek and Chinese culture. In essence, the Greeks (the West), ascribing to monotheism, mind-body dualism (Plato, Descartes), and abstract thinking got us into this mess; and the Chinese, more down-to-earth, systems thinkers (Confucianism, Buddhism, Taoism) can help get us out. It is the Truth vs. the Way.

Now of course this does not do justice to the subtleties of Lent's thinking. You will have to delve into this yourself to fully appreciate his analyses of different patterns of cultural metaphor, but the fact remains that there are some very stark comparisons here between east and west that will not stand up to close scrutiny. To say, for example, in a discussion of the scientific revolution, that whereas Europeans "showed great dexterity in appropriating the new way of thinking as further justification for world domination" (p. 314), the "ultimate objective" for the Chinese cosmological viewpoint "was harmonization: the healthy integration of the individual with society and of humanity with the

2 On the differences between Lent and Dawkins, see Jeremy Lent, "The Dangerous Delusions of Richard Dawkins," Alternet, August 3, 2017, https://www.alternet.org/belief/dangerous-delusions-richard-dawkins; Jerry Coyne, "Response to Lent," *Why Evolution Is True*, August 7, 2017, https://whyevolutionistrue.wordpress.com/2017/08/07/predictably-salon-publishes-a-new-dawkins-hit-piece-and-its-as-dreadful-as-youd-expect/; Jeremy Lent, "Beyond Reductionism: An Open Letter in Response to Jerry Coyne," *Patterns of Meaning*, August 10, 2017, https://patternsofmeaning.com/2017/08/10/beyond-reductionism-an-open-letter-in-response-to-jerry-coyne.

3 Paul Kurtz, "Prometheus Books: Spreading Freethought Worldwide," *International Humanist News* (November 2003): 14-15. Kurtz is the founder and publisher of Prometheus Books which, in turn, is a Specialist Member of the International Humanist and Ethical Union.

natural world" (p. 329), just leaves out too much. There is much more to this story than that. And although Lent does come back around to discuss some of his western culture heroes—Aristotle, the Stoics, the Epicureans, (Thomas Aquinas almost makes it), Da Vinci, Spinoza, Leibniz, the Romantics, Goethe—all of whom understood reality in ways commensurate with eastern thinking, even when he gets to the twentieth century, thinkers like Whitehead, Husserl, Merleau-Ponty, and Heidegger are important because: "Like the Neo-Confucians before them, they recognized that intellect alone did not suffice to comprehend the universe, but skillful use of one's intuition was required for a deeper understanding" (p. 363). Do with this what you will.

The Patterning Instinct is an original and unique historical narrative that combines the scientific with the ethical and the esoteric in ways that remind us that not all science is one, that the divide between science and other branches of knowledge is not as clear cut as we sometimes imagine it to be, and that Enlightenment thinking and Romanticism are not diametrically opposed but are rather entirely bound up with one another in an array of modern cultural metaphors that are shared worldwide. It also reminds us that the way forward is to facilitate dialogue with those whose metaphors might differ from ours as opposed to lowering the gates in the name of methodological purity. We are all in this together.

God in Cosmic History: Where Science & History Meet Religion

by Ted Peters

Anselm Academic, Winona, Minnesota, 2017

and

New Cosmic Story: Inside Our Awakening Universe

by John F. Haught

Yale University Press, New Haven, Connecticut, 2017

Reviewed by Lowell Gustafson *
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These two books seek to establish "cosmic history" by adding religion to big history. There is much to be said in favor of the attempt. Karl Jaspers remains famous for his term: the axial age. The philosophies and religions that appeared in Persia, India, China and the Greco-Roman world from the 8th century BC to the time of Mohammed continue to hold the allegiance of billions of people. These are the axles around which many cultures turn.

It may be that we are in a second axial age. We live in a time of economic globalization, transcontinental air travel, and instantaneous digital communication. We also live in a world defined in many ways by science. These two books seek to integrate the traditions of the axial age with the narrative of our universe's entire known past as substantiated by the sciences. This is an important and worthy effort. Thousands of years of human experience as expressed in the written texts and artistic works that we have inherited provide insights that deserve our serious reflection as we consider the meaning of scientific findings.

It is also an extraordinarily complicated and contentious effort. The principal value of these books is not that they are the last word on the topic; they are not. I will be quibbling with the authors a good deal below. But they set us off on a pilgrimage that calls on others to join as a path forward is gradually developed with many fits and starts through murky terrain.

Science's Effects on History and Religion

In *God in Cosmic History: Where Science & History Meet Religion*, Ted Peters makes an important contribution to our thinking about a crucial set of dialogues among science, history, and religion. His goal is to expand a secular view of big history to one of cosmic history that includes a view of God as its author or co-author.

He reviews the evidence based narrative of the entire past within which the human experience is a most recent part. Traditional historians who limit their research to the great books of the past and other archival materials were not the ones who revolutionized our idea of the past. They restrained their analyses to the human experience over recent decades, centuries, and millennia.

The past of traditional historians was similar to the past of traditional Judeo-Christian religion. Traditional religious calendars were consistent with traditional history. The Jewish calendar starts with the creation of the world and finds us living now 5779 years later. The Christian calendar locates us now living 2018 years after Christ's birth, with earlier events some number of years before Year 0. Dating events with years Before Christ, or B.C., was manageable if the time between Christ's birth and the

*I appreciate that David Blanks suggested revisions of this review. Of course, I am solely reponsible for any inaccuracies or other faults in it.

creation of the world was a few thousand years. Both religious traditions placed humans in a past of 6,000 years or so. Traditional history and Judeo-Christian religion gave much of humanity its sense of when it had lived in time. Reading archival materials and sacred texts gave no hint that time was much longer than had been thought.

It was the geologists first, and then biologists, astronomers, and others who found the evidence that blew up this sense of where we are in time. Their analyses of light, stones, bones, and blood established a past that reaches back millions and billions of years. Peters takes the scientific narrative of the past as a given. His view of religion has nothing to do with Young Earth Creationism. His view of history shares with big history the realization that the known past does not begin with the written record of humans some thousands of years ago, but with the origin of our known universe 13.82 billion years ago. He then goes through the major developments between the big bang and our own time: the origins of stars and galaxies, our solar system, Earth, life, the evolution of complex life forms, and eventually the evolution of hominins and humans. He accepts that human nature comes out of the fuller story of nature. The story of the entire past can be studied only with the help of the sciences. All of this is familiar territory for big historians, if not traditional ones.

Myth, Symbolism, and the First Axial Age Religions

Peters follows his review of the evidence based narrative of the entire known past with a discussion of myth and symbolic thinking by hominins and humans before the development of writing. Exactly how consciousness and self-consciousness, language, purpose, and symbolic thought developed – or even exactly how to define them – is not yet clear to anyone. From the time around 3.8 billion years ago when the first prokaryote cell used its flagellum to move towards the light or away from danger to a time just hundreds of thousands of years ago of coordinated human activity, when did consciousness and purpose develop first? When and why did religious thought and practice develop first? There is considerable evidence that our early ancestors thought about and practiced religion for tens of thousands of years before there were any sacred texts. They often buried their dead with grave goods, suggesting views of an after-life. Their artwork deep in caves from tens of thousands of years before any sacred texts were written suggest religious ritual. The human religious experience before any of the great current world religions were developed is part of the archaeological and historical record that big historians well recognize. The insights of our ancient forbearers continue to merit reflection.

Following this discussion, Peters then examines the two Biblical Genesis creation accounts. He usefully reminds us that the first creation account may have come from a Priestly tradition that was told to ancient Hebrews who were in captivity in Babylon in the sixth century BCE. This suggests to me a political reason for the creation account in Genesis. If the belief was that Yahweh or El, two names for the Hebrew god, was powerful and promised the Hebrews their land in Canaan, then why were they held in captivity in a far-away empire? The answer they seemed to have given themselves was that their God created all the world, controlled their captors, and used the Assyrians and Babylonians to punish themselves for their own wrongdoings. The Hebrews' captivity proved to themselves that their captivity was a sign of their god's power. Their account empowered themselves as captives. The lesson they drew was not to repeat the mistake of disobedience but in the future to scrupulously follow the law. When they wrote this into their religious texts, it was a case of the losers writing, if not history, then what would become very influential ideas. They used their best understandings of nature to express a deeply felt need for meaning and identity in a hostile setting. The creation account may not now be useful as a literal account of exactly how nature emerged, but it is inspiring in the social and political message it developed in the face of hostile conditions. Even in the absence of evidence that the near-term future would be better, the authors or editors seemed to tenaciously hold on to their identity and their hope.

Peters then widens the discussion by covering the cosmologies of Daoism, Confucianism, Hinduism, Buddhism, ancient Greek philosophy, and Islam, in addition to Judaism and Christianity. It is useful in our globalized era to consider what we can draw from all of humanity's profound expressions and insights over the millennia. It is helpful not only to think about what various religious traditions meant to those who practiced them in the past, but also for what we might learn from them now. Peters contributes to our efforts to learn from all past cultures and to see what resonates now in our own time. The attempts to integrate science with what is still true about all religions that originated in the first axial period make our own time something of a second axial age.

Peters then reviews various models of God. He discusses a range of ideas about what or who God is or is not. We may still need a fuller discussion about what "God" means in our scientific and global age. We need the humility of the sciences in not saying anything too confidently about God when we really just don't know. There could be an arrogance in asserting that God is this or that way because we assert it. And there is reason to wonder if we know who God is because a group of men got together and agreed about a definition or if statements are found in texts. At least religion needs to find ways to discuss God now in a time when increasing numbers of people question claims about God based exclusively on evidence found in sacred texts and the writings of great thinkers. Once we stray from measurable evidence, religion finds many less interested in dialogue about God. Assertions about God's existence or nature by citing tradition or sacred texts for authority do not serve dialogue. We are still searching for how we can best talk about creativity, what is beyond current evidence, love, being faithful, hope, the relationship between the universal and the personal, ethics, and other topics in ways that are consistent – or at least not inconsistent – with religious traditions and science.

Peters concludes his book with a discussion about what finding extraterrestrial life might mean for religious traditions, and how his topics may affect the sustainable common human good. How can we draw on our traditions to imagine what is not yet, but what we may be able to create, and then be able to say that it is good? There may be room for dialogue between cosmic historians and big historians within the idea of emergent complexity. Beginning with relatively simple plasma and then over time in some areas going through a process of increasingly complex relationships among parts within new units is a story of natural development. Nature shows us that not only are there new things under the sun, but that suns and stars were (and still are) themselves something new. Nature can move beyond what there had been evidence for beforehand. Can we say that nature transcends itself? Is transcendence part of nature? Is nature sometimes inherently creative? Can we find a process of increasingly complex unities among much that had not been unified? Does this process of self-organization or self-creation need an external author?

Do traditional historians say that God authored this or that event in history? Humans' beliefs may have a good deal to do at times with what motivates them to act, but does this show that a God was the author of this legislative bill or that judicial decision? Do we need a God to be involved in the Krebs cycle in order to find religious traditions of value? Are there better questions about God than if nature has an author?

From Big History to Cosmic History

Throughout, Peters works to integrate science, a number of great religions and philosophies, and big history in what he calls a cosmic history. The difference between big and cosmic history is that the latter considers what he calls the God Question and how this can improve the human condition. This is an important effort and Peters contributes much to the discussion among those who share an interest in religion, science, and history. A slogan of the Augustinians, who founded and continue to run the university where I work, is "Ever Ancient, Ever New." Every age must reinterpret the traditions they inherit and express what they draw from the past in ways that resonate with contemporary culture and knowledge. Peters is seeking to do that here.

But his question about if God is the author or co-author is not a question that big historians would know how to answer with available evidence. Peters does indeed take his discussion beyond what most big historians find evidence to discuss. He asks a question that they would not know how to address.

There are a few points to quibble with regarding how Peters' defines cosmic history and then a larger issue to consider. First, the quibbles. Peters contends that cosmic history differs from big history in three ways: 1) cosmic history raises "the question of human meaning through remembering the past," 2) it traces "the differentiation of human consciousness," and 3) it raises the "question of God" (page 18). I see no difference between big and cosmic history in the first two cases. When I search for "meaning" in Christian, Brown, and Benjamin, (2014), I get 107 matches. On page 2, they write, "And mapping our world like this can give us a powerful sense of meaning."[1] Books by secular scientists include such examples as *The Big Picture: On the Origins of Life, Meaning, and the Universe Itself* by Sean Carroll, or *The Meaning of Human Existence* by Edward O. Wilson. Meaning is not unique to religion. A quick bibliographic search on science and the evolution of {human} consciousness will also yield many results. Cosmic history has no monopoly on an interest in consciousness. Even in the third case, big historians do indeed raise a God question. A search of "god" in Christian, Brown and Benjamin's big history textbook yields 85 results; a search of "religion" yields 51 matches. The authors discuss god and religion quite a bit. Admittedly, they do not ask the same God question that Peters does. Big historians ask when, where, and why in history do people leave evidence of thinking about gods and religion. Some big historians are interested in religion as an emergent cultural phenomenon, but they are not very interested in questions about God. It is true that they do not begin by assuming that there is a God or ask if God is the author of history. But asking if God is the author of cosmic history is not the only way to raise a God question. Big historians often do fall into the atheist or agnostic camps. They do not deny that religion is interesting and important; they just do not assume that God exists or that they know how to find evidence for God's effect on matter, stars, galaxies, evolution, and so on.

There is the old problem of the "God of the gaps" argument, or using God to explain whatever we do not yet understand. For example, Peters refers to an argument on page 156 that goes like this:

Whatever begins to exist has a cause.
The universe began to exist.
Therefore, the universe has a cause.
This cause is God.

Scientists who do not yet know the cause of the big bang usually leave it with that they do not yet know. They don't give what they do not know a name, like mystery. They just say they do not know yet. (Admittedly, there is some talk about a theory of everything, which is a very long way off and probably always will be). Lawrence M. Krauss, in his book *A Universe from Nothing: Why There Is Something Rather than Nothing*, argues that there is indeed a scientific explanation for the origins of everything. If it is God who caused something in nature, many scientists and big historians would want

1 Christian, David; Benjamin, Craig; Brown, Cynthia. *Big History: Between Nothing and Everything* (Page 2). McGraw-Hill Education, 2014.

to know the evidence for this claim beyond asserting that it is so. How do we know that the God who transcends nature forms it? Is the question central or even pertinent to what religion can contribute in our time?

Authoring Reality

The question about if God is the author of cosmic history does intrigue me. It sees natural development essentially as a narrative. Nature is a story. It is a little bit like the idea in Max Tegmark's book, *Our Mathematical Universe: My Quest for the Ultimate Nature of Reality*. Tegmark finds ultimate reality to be about computing information or equations; Peters' Ultimate Reality is about authoring nature. Is the universe a story or an equation?

Peters' idea of God authoring nature may have come from the Genesis story in which God speaks and that brings nature into existence. "God said, "Let there be light," and there was light." Nature is the embodiment of God's words. It is the spoken word here though, not the written word. To be consistent with Genesis, perhaps the question should be if God is the Speaker of Ultimate Reality. I remember hearing a rabbi saying once that a good reason to study Hebrew is that this was the language God used to bring the universe into existence by speaking.

What strikes me as important about the idea of God's (written or spoken) words being the source of reality is that whoever first spoke or wrote the Genesis story was impressed by how imagination and discussion could then lead to planning and building something new. There were no cities, and then people talked and worked together to carry out plans to build them. Maybe the context for Genesis is that people said, let there be art, architecture, agriculture, and other things – and then they existed. Language is indeed powerful. Words can turn sticks and stones into civilizations and fearsome armies. That is worthy of marvel, awe, and fear.

Still, I do not see a way to find evidence that will support dialogue in our era in ways that will answer the question if God is the author or at least co-author of history – or even what "ultimate reality" is. How do we know when we have moved from reality to its ultimate version? We seek our best approximations of reality through analysis of evidence and our best conceptual systems. Claims to full knowledge of ultimate reality have a taste of hubris. In religious terms, we need to beware of the idolatry of unfounded claims. Religion's untestable claims to a total account of ultimate reality – or scientists' claims that they might find a theory of everything – are equally arrogant and unsupportable. One lesson of religion and science is humility; both know at their best that God and reality are always beyond them. The reluctance by some to even name G-d is based on the understanding that to name is an attempt to control, and that G-d is beyond our full understanding or control. Of course in practice, while many in religion and science are often wrong in their claims, they are seldom in doubt.

Unanswered questions

Does the value of religion rest on whether or not there is a transcendent person who sets stars in the sky, puts together every molecule, or causes every mutation? What can we learn from our religious traditions that is not inconsistent with what else we now know? What can we draw from them that resonates in our own time? What in them should be left behind as of historical interest but not of current instructive value? How can we avoid the hubris of thinking that only our own age exhibits brilliance and insight? What can we say that satisfies us as being as true as we can know it now, expecting that it may well change as we learn more? How can we integrate what is both ancient and currently instructive? How can all this lead to us imagining, planning for, and helping to create a future that is sustainable, empathic, caring, inclusive, and good?

Ted Peters adds to a discussion that is taking place along our current pilgrimage, but he would be the first to say that is not the final word about ultimate reality. It does not answer the question about God, or maybe even ask it well enough. But his effort to struggle with these huge issues, and our willingness to listen to him and then try to respond as best as we can, may eventually make our era a great second axial one, if we don't cause our own extinction first.

New Cosmic Story: Inside Our Awakening Universe by John F. Haught is a sophisticated book. John Farell, who contributes on science and technology to Forbes magazine, names it as his book of the year.[2] In it, the author explores a series of topics by drawing on great religious traditions to interpret contemporary, scientifically-substantiated narratives. He does not merely repeat specific stories or propositions from earlier historical periods, but recasts discussions about rightness, transformation, interiority and subjectivity, transcendence, symbolism, purpose, obligation, happiness, and prayerfulness. Clearly, he is deeply influenced by his Roman Catholic education, but he strives to incorporate other Abrahamic and non-Abrahamic religions and philosophies. And he takes for granted the contemporary, scientifically substantiated narrative of universal development. As with Peters, Haught is no young Earth creationist. He states that "religion all over the world needs now to come to grips with the new scientific understanding of the natural world." (Kindle Locations 415-416). In this, he sets off on the right path.

Also, like with Peters, Haught finds big history accurate as far as it goes, but seriously lacking by leaving the "interiority" of religion out of the account. Scientism and big history examine the external behaviors of religion, but not the "interior" of the universal narrative, or even what a universal interior would be. They will analyze why people have expressed religious beliefs through art, architecture, and sacred texts, but do not see anything inherently religious within the progression from the big bang through today and into the future. This failure has caused, Haught argues, some serious effects, discussed below.

Haught begins his book by contrasting cosmic history with big history. He accepts how "over the past two centuries scientists have found out that the universe is a story still being told. During the past hundred years they have learned that our Big Bang universe began billions of years before life appeared and even more billions before humans arrived on planet Earth. New scientific awareness of the long cosmic preamble to human history has inspired attempts recently to connect the relatively short span of our own existence to the larger cosmic epic. Sometimes these efforts are referred to as Big History. Big History seeks, as best it can, to tell the story of everything that has taken place in the past, including what was going on in the universe before Homo sapiens arrived."

He finds that big history is pretty thin gruel. It takes the already well known human story and staples it onto earlier cosmological and biological chapters, which do no more than repeat what is already in popular science books. There is no interlacing of the various periods. Most importantly, there is no account of the universe's "interior" or inside story. By restricting itself to scientific evidence, it fails to observe that the universe "includes subjects, hidden centers of experience whose significance cannot be measured by science or captured by purely historical reporting." He continues, "Startlingly absent from Big History so far, for example, is a sense of how religion fits into the cosmic story. This book is an attempt to address this omission." Haught will tell a narrative that "tells the whole cosmic story, inside as well as outside."

That whole story highlights "the interior striving of life that reaches the summit of its intensity in humanity's spiritual adventures. . . . {The} emergence of religious subjectivity, though hidden, is just as much part of the universe as is the formation

2 John Farrell, "Book Of The Year: The New Cosmic Story." *Forbes*, December 31, 2017, https://www.forbes.com/sites/johnfarrell/2017/12/31/book-of-the-year-the-new-cosmic-story/#420cbe8f478b, last accessed, December 31, 2017.

of atoms and galaxies." (Kindle Locations 41-58). Unlike big history, cosmic history tells a story about the "dawning of rightness. . . ." This dawning "was not just a set of interior human intuitions but also a great event in the history of the universe" (Kindle Locations 241-242).

Archaeonomy, Analogic, and Anticipatory

The book is organized by three main viewpoints: archaeonomic, analogical, and anticipatory. The archaeonomic is a narrowly scientific viewpoint, into which big history is said to fall. It is interested only "in outward, measurable events and qualities, it passes over the inside story" (Kindle Locations 556-557). There is nothing inherently meaningful nor purposeful in the universe as a whole, in this view. Religion is a human-made construct that is not rooted in the long universal pre-human past. Scientific naturalism sees matter and energy as all that exists. It understands the more complex units by their elemental parts; it is reductionist. Haught writes that David "Christian fails to look beneath the outward flow of events to the momentous drama going on inside" (Kindle Locations 1174-1175). Haught contends that "archaeonomic assumptions govern most versions of Big History, including its understanding of religion" (Kindle Locations 738-739).

The analogic viewpoint is a common religious viewpoint. It sees the changing, imperfect, material world as analogous to an eternal, invisible, and more real world. Haught sees this viewpoint as having been nurtured by his own tradition of Roman Catholicism.

He does not explore the Gnostic viewpoint, but that too emphasized how we each have a glimmering spark of the real world in us. Knowledge of the real and good world is hidden from most of us, who are usually blinded by our imperfect, evil material world created by a malevolent deity. For the Gnostics, if we can strip away the masks of the evil material world and gain a true knowledge of the real and good world, we can escape materialism and evil. When we die, that eternal spark, the unmeasurable soul, can go to live with the eternal good God.

Gnosticism aside, what Haught emphasizes is how the analogic viewpoint seeks to awaken us to the whole world; science only to the material world. Haught sees the archaeonomic as dangerously lacking insight into the "inside story" of the universe. Haught respects the analogic viewpoint, but finds it far too binary. There are not two separate worlds for Haught. He does not see terrestrial battles on Earth mirroring metaphysical battles in Heaven. He seeks a unity that holds diversity within it.

Haught argues for "anticipation" as the best way to read the cosmic story. Time is real and not merely a school for eternity. When we look back to the past, we see the emergence of what is more good, true, beautiful over time. As we look to the future, we anticipate and actively wait for the fuller emergence of rightness, including right knowledge (truth). The universe has in the past awakened to life; this took place on Earth about 3.8 billion years ago and perhaps on other planets as well. Through a very long process of evolution, which Haught accepts, there is not only a development of highly complex brains that process information and regulate biological functions. The universe brings forth consciousness and the mind, which permits at least humans to become God-conscious. The universe continues to awaken to greater forms of rightness. This is not just a human construct; it is rooted in the nature of the universe, Haught asserts. Our anticipating it, our waiting for it, our praying for it, all participate in the emergence of greater universal rightness.

This is the interior of the story that the scientific method cannot discover. Scientific measurement cannot discover the interior experience of persons nor of the universe. It only can measure the external, objective behaviors of people and the universe. The religious person can sense the interior story not only of a person, but of the universe. The dawn of religion is “a new stage in a gradual cosmic awakening. It looks toward a universal religious meaning arising obscurely on the future horizon of cosmic becoming” (Kindle Locations 753-754). “Religion in this perspective is the universe in a whole new era of awakening” (Kindle Location 766). “By the “inside story,” then, I have been referring to all the events that occur in the hidden world of subjectivity. It includes sensations, moods, cognitions, desires, enjoyments, and—in the case of humans—moral and religious awareness, aesthetic sensitivity, and the longing for understanding and truth” (Kindle Locations 1187-1188). Even before humans, the universe has an interior story including “sensations, moods, cognitions, desires, enjoyments.” The universe is a community of subjects with interior stories, not merely lifeless and mindless objects without purpose or striving. In human religious consciousness, the universe is able to reflect on itself. The dawn of religion on Earth somehow has significance for the universe, presumably including for stars in galaxies billions of light years away.

At best, “the virtual elimination of subjectivity from the cosmos by modern and contemporary thought renders most contemporary versions of Big History intolerably thin” (Kindle Locations 1305-1306). But thinness is the least of its problems. The objectification of the universe that the archaeonomic and big history viewpoints have fostered have had profoundly insidious effects.

“{The}explicit denial of subjectivity has contributed at least indirectly, I believe, to the formation of intellectual and cultural beliefs that have in turn facilitated the mass killings of the twentieth century. It is still impossible for most of us to get our minds around the specter of many millions of people being slaughtered during this period as inconvenient objects standing in the way of the implementation of the economic and engineering visions of a handful of men such as Hitler, Stalin, Mao, and Pol Pot” (Kindle Locations 1272-1275).

When there are accusations of others being the cause of Nazism, Stalinism, and genocide, you know that discussions are not going well. It is hard to put dialogue back on track after such a train wreck. It may be that Haught read one too many criticism of religious wars and decided to respond in kind.

Once we do clear that wreckage away, we can get back to Haught’s anticipation. We can read his views that human art is an awakening of the universal striving towards beauty. The human intellect is an awakening of universal striving towards mindfulness and right knowledge. Human ethical thinking is an awakening of the universal striving toward the good and obligation. After billions of years of development, “Thousands of years ago it {the universe} embarked on a process of transformation that eventually gave rise to religion, and along with it a sense of the reality of rightness” (Kindle Locations 967-968). Universal transformations are a form of religious conversions or awakenings. The religious developments among people within the past thousands of years is a significant universal awakening, Haught asserts.

Places for Dialogue

Haught fails to see where in big history there may be a place for dialogue with a view of anticipation. He argues that the archaeonomic viewpoint, including big history, “denies, in effect, that anything genuinely new can ever happen in the cosmic story” (Kindle Locations 1012-1013). He continues that in the archaeonomic and big history viewpoints, “there is no room in this metaphysics for the universe ever to become more than what it has already been. Real cosmic transformation in the sense of bringing about something dramatically new and remarkable is therefore altogether impossible” (Kindle Locations 1041-1043).

He does recognize finally that “We live at a time in intellectual history, it is true, when physics itself has begun to vanquish materialist and deterministic concepts of nature, when the notion of emergence is struggling to replace mechanism, when the analytical illusion is giving way to a more ecological understanding of the cosmos, and when time is beginning to be taken, once again, as real" (Kindle Locations 3120-3122). What he never recognizes is that this is a central part of big history, which emphasizes emergent complexity with new levels of complexity exhibiting new properties. The whole thrust of big history is that it starts with an account of simplicity and then presents what becomes more and more complex.

With the story of human collective learning, it emphasizes how human agency has transformed the Earth. Humans imagine, plan, and build. In this, they not only anticipate and wait, they create new realities. Not all of these new realities have been good, to be sure, but many have been. Medical science and the welfare state's public policy often reject evolution's "wrongness" that most mutations should just be permitted to cause death and misery. Instead, humans often seek to help those with various disabilities to survive and thrive. Many humans try not to emulate some animals in pushing smaller or deformed youngsters out of the nest to a fatal fate. People can search for this increased rightness through religious or secular motivations. The big history theme of emergent complexity is a place for dialogue with anticipation.

Similarly, there may even be a place for dialogue regarding the idea of transcendence. The idea of anticipation tries to avoid the analogic view that there is a wholly separate, metaphysical, eternal world that is distinct from, but somehow interacts with this changing, imperfect, even evil material world. Big history's theme of emergent complexity suggests that natural processes of self-organization have often moved what exists in nature to a new level of complexity. First there was only protons and neutrons; then there were atoms. There were no stars and then there were. There were no terrestrial planets and then there were. There was no life and then there was. Can we say that nature has often transcended itself? Does not the experience of the past suggest that there may again be the formation of new levels of complexity that do not now currently exist? This process is not caused by outside forces, but is part of how the universe has worked for billions of years.

In general, religious people need to find places for dialogue with science. Ignoring where there can be dialogue, or condemning it as the cause of genocide, fails to enrich the understandings of each set of discussants.

Awakening to Analogic Viewpoint?

Haught's view of anticipation intends to move beyond the analogic viewpoint without falling into pantheism. He does not want to view the universe as an imperfect mirror or school for eternity. He wants to avoid the binary thinking of Heaven and Earth, of this world and the next. In life and in death, he sees us as part of a universal emergence towards rightness. Still, he does not want to deify nature, or suggest that God-consciousness is merely the love of nature. But is there in this a hold-over from the analogic viewpoint? If the universe is awakening, is it awakening to something that is already there? Is it being led by a telos, a purpose, a direction for the future? Big history emphasizes the past; cosmic history emphasizes the future to which we and the rest of the universe are being awakened.

Haught insists that the process of being awakened to rightness is inherent in the universe. It is not just human imagination. Human imagination, waiting, and anticipation are the outcomes of universal emergence. To a degree, I agree. I have argued myself that human art is the self-conscious creativity that emerges from nature's emergent complexity. But this is no uniform process. The future, like the present and the past, seems often to be right, wrong, or indifferent. First of all, will it be right or wrong as we anticipate the Milky Way and the Andromeda galaxy running into each other in the future? What is the more right way of galaxy formation? Species evolve and go extinct. The death of the dinosaurs opened up the way for mammals and humans to thrive. The death of a huge star 5 billion years ago made the formation of the Earth possible. Big history is an account not just of death, but of death and life and rebirth and death and . . . . Is it wrong that trilobites are no longer with us? Would the universe be at a loss if humans and human religions no longer survived? It is hard to see how the universe is striving only for rightness, or striving for anything in particular.

The long term future of Earth is indeed death. Five billion years from now, once the sun becomes a Red Giant, Earth will be a cinder. One view of the long-term future that we can anticipate is the big chill, or the dissolution of the universe and the victory of entropy. That is not big history's fault, it is just our best current understanding of where the universe is ultimately headed. Will other universes emerge? Have they already? Maybe the multiverse is teaming with universes the way our universe is teaming with galaxies and stars. Maybe science will find evidence for views that the multiverse is teaming with life. What I anticipate is what science will discover about these possibilities in the future.

God-Consciousness

Can there be dialogue between religion and science about God-consciousness? Probably not if God is said to be a spirit who flies around creating stars and humans and such, as God does in much popular consciousness. If God-consciousness is an awareness that we have not made ourselves, but that forces that far predate us led to our having arms and legs and brains, then there is place for dialogue. If we are awed by the immensity of the universe and the complexity of life, if we strive to leave our world a bit better than we found it, if we seek to help create even more complex and sustainable relationships, if we are grateful that we can even try – then there might be common ground for dialogue.

The root word of religion may derive from Indo-European *ligājō* and the Latin word religare, both of which mean to bind together. It may be that the natural sciences examine in part how atoms and amino acids and cells are bound together in increasingly complex relationships. The social sciences, humanities, arts, and religious imagination may express the most complex ways in which humans bind themselves together in larger and sustainable communities. Complex relationships did emerge in a few places out of simpler units.

Most of the time, there was no emergence. Vast clouds of hydrogen that are billions of years old still float in space, largely unchanged wince the big bang. Prokaryote cells that are no more complex than they were 4 billion years ago still thrive on Earth. The universe has led to great complexity in a few places; most of the time it does not become more complex. But history is made possible by where there is emergent complexity; hope can be found from the imagination and anticipation that can create new properties within even more complex relationships than what we see now.

Perhaps science and religion are both best when they remain humble. Scientists should avoid making claims about a theory of everything, admit that there is just an awful lot that they do not yet know, and accept that a full understanding of reality will probably always be beyond our grasp. Religious people should be careful about naming and thereby trying to control what they do not fully understand. In the spirit of these two books by Peters and Haught, we need to continue to draw from the brilliance of our human cultural and religious traditions as we reflect on the evidence that the sciences have given us to substantiate a narrative of universal development. Both authors deserve our praise and gratitude for inviting us into struggling with these great topics.

Big History and Cosmic History: A Response to Lowell Gustafson

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Lowell Gustafson likes humility. He admonishes both scientists chasing a Theory of Everything (TOE) and theologians chasing God's essence to remain humble, to avoid the hubris evinced by claiming to know too much. This is sound advice. Humility should adorn science, theology, Big History, and Cosmic History alike.

Gustafson exudes the very humility he advises while reviewing John Haught's new book, New Cosmic Story: Inside Our Awakening Universe (Yale 2017) and my new work, God in Cosmic History: Where Science and History Meet Religion (Anselm Academic 2017). Both Haught and I celebrate the achievements of Big History while pleading for something to be added, namely, greater attention to both subjectivity and transcendence. Gustafson accurately reports our proposed amendments to the Big History constitution, while adding that Big History as now constituted already makes satisfactory provision for our proposed ammendments.

As an author, I could not ask for a more conscientious review of my work than that offered by Gustafson. He is careful to be accurate and judicious in his criticisms, what he calls "quibbles." As a member of the IBHA, I am proud that Gustafson is our current president.

Here is one of Gustafson's quibbles: he questions my bold assertion that Big History as presently constituted falls short of handling adequately subjectivity, transcendence, and meaning. To the contrary, Gustafson contends vigorously, big historians frequently use the term 'meaning' in their works. Meaning is not unique to religion, he argues. Cosmic history has no monopoly on an interest in consciousness, or what Haught calls 'interiority'. And, of course, religion as a phenomenon is chronicled by some big historians. So, why do Peters and Haught have a problem here? Why can't Peters and Haught simply say "thank you" to what big historians have already done?

The problem is primarily methodological. Even though Haught and I can celebrate the nesting of World History into Natural History to create Big History, the problem is that Big History is now viewed through lenses provided by science and science alone. Specifically, it is evolutionary science (augmented sometimes by the sociobiology of E.O. Wilson which is virtually a pseudo-science) that sets the gauge for what gets filtered. Whether evolutionary biology or any similar science, such a field presupposes methodological naturalism which filters out everything that does not lead to a material explanation. Such a method is characterized by objectivity, externality, non-teleology, and meaninglessness. Phenomena systematically excluded as explanatory are subjectivity, transcendence, and meaning.

Methodological naturalism within scientific research is understandable and appropriate. This methodological assumption has demonstrated the capacity for producing new and valuable knowledge for three centuries now. But, one must ask, could methodological naturalism provide explanatory insight into history, especially when history to be history cannot avoid the meaning question? For the big historian to answer in the affirmative would lead to either self-contradiction or ideology. Whatever a big historian says about meaning is either arbitrary or ideological; it cannot arise naturally out of its research method. What needs to be made clear is this: no historical understanding is reducible to the methodological naturalism already embraced by the natural scientists. In short, the method of big historians is incoherent.

Yes, indeed, I ask whether God might be the author or co-author of Big History, and this asking catapults my approach into Cosmic History. In Greco-Roman times, the cosmos represented the known world, the scope of mundane reality. In pre-axial societies, gods and goddesses along with other supra-human forces were thought to be intra-cosmic. During the axial breakthrough two and a half millennia ago, however, reality became bifurcated into the mundane and the transcendent. Divinity became thought of as supra-cosmic, infinite, and eternal. Lodged in transcendent and eternal reality with God, our ancestors thought, were the ideals which still matter to us today in our post-religious era, namely, beauty, truth, and justice. Justice is especially significant for us in modern culture, because it provides the transcendent beacon shining a light to guide us from the darkness of injustice to a more just future.

The only place to see the effects of divine transcendence is in the human soul, in subjectivity or interiority. God cannot be located among the things of the natural world, nor can God's actions be numbered among the physical causes which explain natural events. To see God requires that we see within the depths of ourselves; it requires insight or in-sight, so to speak. God and the soul come together in a single package. Insofar as big historians rely upon the worldview implied by methodological naturalism, both God and the soul become imperceptible. To sharpen our perceptions, Haught and I in similar though not identical ways advocate moving from Big History to Cosmic History.

The New Cosmic Story: A Response to Lowell Gustafson by John F. Haught

John F. Haught
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I want to thank Lowell Gustafson for his review and the spirit of dialogue and honest intellectual exchange underlying it. We need this kind of calm and urbane discussion more than ever today. In general his summary of my book is fair and for the most part accurate. I will just say a few words here about several of his "quibbles."

1. Evidence. When he complains that neither Ted Peters nor I provide what he calls "evidence" for our understanding of cosmic history, Gustafson is apparently privileging the kind of physically available information on which science is based. Neither one of us thinks that the only kind of evidence that counts is the modern scientific variety. Depending upon one's worldview, the kind of warrants needed for a particular set of convictions may differ considerably as we migrate mentally from one vision of reality to another. Moreover, there can be no "objective" evidence that scientific evidence is the only reliable kind, especially when it comes to knowledge of interiority. To privilege the subject-ignoring, objectifying method of knowing characteristic of modern science (and idealized by most Big History) is ironically a matter of subjective "faith," not the result of any deliberate process of objective scientific investigation. Consequently, to expect confirmation of such a momentous idea as that of divine subjectivity by way of objectifying scientific inquiry is by definition misdirected. For this reason I think we need to examine the possibility that there are other ways of truthfully knowing reality than that of the exclusively objectifying approach taken by much Big History. This is especially true if there is an "inside story" of the universe.

2. Emergence. The reviewer asserts that proponents of Big History are no less aware of the fact of emergent novelty in the cosmic story than I am. In fact, however, I do not deny that Big Historians are aware of emergent novelty. Almost everybody is. My point is that a materialist or what I call "archaeonomic" understanding of the universe cannot make emergence fully intelligible. I believe that the materialist reduction of complexity to elemental simplicity amounts to a de facto denial of true novelty. I argue that the existence of the human mind is our best indication that a materialist worldview is incapable of making sense of emergence. The recent arrival of the human mind is perhaps the supreme example of emergent novelty in cosmic history, but we cannot appropriately use our minds without spontaneously trusting in and valuing their capacity for understanding and truth. I want a worldview that can justify this valuation and trust in our cognitive performances, and scientific materialism cannot do so. Think, for example, of the implicit value Lowell Gustafson gives to his own mind in writing his fine review. I want a vision of reality that justifies that trust, and I do not find it in the materialist assumptions underlying most Big History, but instead in the "anticipatory" reading of the universe that I lay out in The New Cosmic Story.

3. Subjectivity. I argue in the book that the failure to acknowledge the reality of subjectivity is morally dangerous and culturally devastating. I do not argue that modern scientistic secularity is responsible for all the mass killings of the 20th century, since things are obviously more complex than that. Furthermore, I take pains in the book to point out how much religion has been tied up with the persisting darkness of evil in our awakening universe. Nevertheless, I consider morally problematic any worldview that overlooks the fact of interiority or subjectivity, that turns everything real into something that can be objectified, and that hence makes no ontological space for personal subjects. In that sense I am very critical of the modern materialist, archaeonomic understanding of the universe since it provides an intellectual setting that can too easily allow political powers to reduce subjects, both human and nonhuman, to nonentities.

My argument with Big History is that, by privileging the objectifying method of knowing, it tends to perpetuate a problematic ignoring of interiority and subjectivity. What I seek instead is a scientifically literate worldview that still makes room for an inside story of the universe to go along with the outside version. Only such a universe can provide full space for personal existence, value—and genuine hope.