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Abstract

This article summarizes the Tree of Knowledge (ToK) System (Henriques, 2003; 2011), and compares and contrasts its depiction of cosmic evolution as four "dimensions of existence" (i.e., Matter, Life, Mind and Culture) with Big History's eight thresholds of complexity. Both systems share the concern with the current fragmentation in academic knowledge and advocate for a more consilient and integrative vision that places the disciplines in coherent relationship to each other, and both views argue that such efforts are needed to advance wise decision making in the context of the accelerating rate of change. The major differences between the two perspectives are found in how the ToK conceptualizes the different dimensions of existence. Following Matter, the dimensions of Life, Mind and Culture are seen as emerging as a function of different semiotic or information processing systems that give rise to strongly emergent properties. In addition, given its emphasis on psychology and the mental dimension of existence, the ToK highlights some aspects of cosmic evolution that have not been featured prominently in most models of BH. The article ultimately suggests that there is potential for a fruitful synergy between the historical emphasis of BH with the more psychological focus of the ToK System.

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The Tree of Knowledge (ToK) System (Henriques, 2003; 2011) is an integrative approach to scientific and humanistic knowledge that shares much in common with the Big History movement (Christian, 2017), even though the two visions were conceived of and developed independently. Central to the ToK System is a series of diagrams that offer a pictographic representation of the "unfolding wave of behavior" that has emerged since the Big Bang and has continued through the present. Because the ToK System is a representation of cosmic evolution and emergence on the dimensions of time and complexity, it is appropriate to characterize it as a Big History (BH) view of the universe, albeit a unique one. Indeed, it can be considered an explicit map of what some scholars in Big History have called "The Great Matrix" (Grassie, 2018). More specifically, the ToK System offers a new, systematic emergent naturalistic metaphysics (Cahoone, 2013) that defines key ontic concepts (i.e., Matter, Life, Mind, and Culture), and specifies their relations to one another and scientific knowledge about them. Figure 1 depicts the primary ToK System diagram (Henriques, 2003), and corresponds it with the eight Big History Thresholds.

As shown, the ToK characterizes the universe of behavior as consisting of four different dimensions of

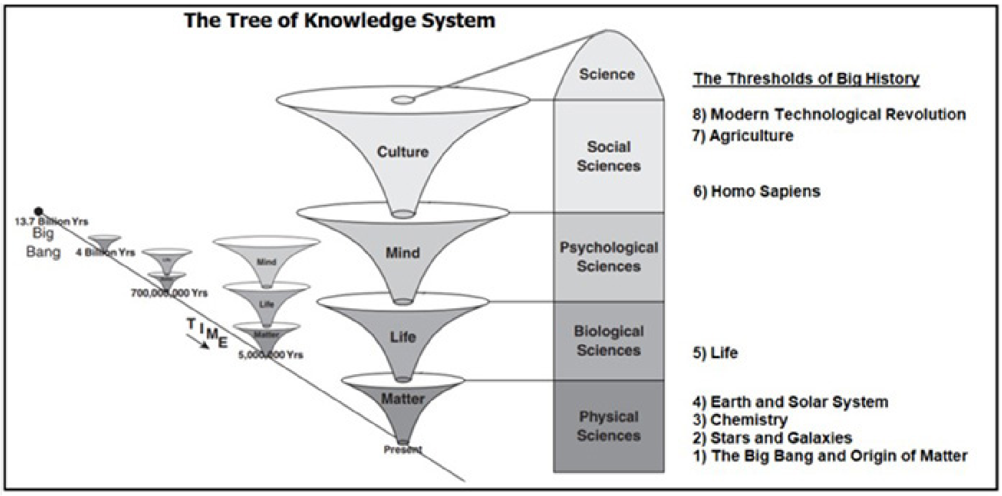

Figure 1. The Tree of Knowledge System and the Thresholds of Big History

existence. The "Matter" cone at the bottom represents the emergence and behavior of inanimate material objects from the time of the Big Bang, and includes entities such as atoms, stars, and planets. Particles like electrons represent the base of the cone as they are the simplest entities, whereas entities like macromolecules found in organic chemistry correspond to the top of the material cone. The "Life" cone represents the behavior of organisms, ranging from the simplest single-celled creatures (e.g., bacteria) up through large, complex multi-celled organisms (e.g., an oak tree). The "Mind" cone represents the behavior of animals with a brain, ranging from nematodes at the base (i.e., worms with simple brains) through highly complex and sophisticated animals, like chimpanzees, dolphins, and elephants. Finally, the "Culture" cone represents the behavior of human persons embedded in linguistic traditions and sociocultural historical contexts. It ranges in scale and complexity from individual persons to the behavior of modern, complex nation states or other societal structures organized by large-scale systems of justification (such as the United States of America).

As shown on the right side of the diagram, the ToK System includes the institution of science, which is depicted as emerging out of the dimension of Culture. What is specifically being represented are the theories, ideologies, and assumptions that guide the scientific enterprise, coordinate the behavior of scientists, and constitute scientific knowledge. In the language of the ToK, these conceptual ideological representations are characterized as "justification systems" (Henriques, 2011; Shaffer, 2008). Thus, the ToK depicts how the physical sciences map the dimension of Matter, the biological sciences map the dimension of Life, the psychological sciences map the dimension of Mind, and the social sciences map the dimension of Culture. We can use the philosophical difference between ontology and ontic reality to achieve conceptual clarity in understanding this correspondence. As represented here, the sciences consist of the ontological knowledge of the actual, ontic entity. For example, the theory of general relativity represents the scientific, ontological understanding of how massive bodies curve space and time. As a theory about the material world, it resides in the matrix of the physical sciences, and thus is a part of the Cultural dimension of existence. However, the ontic behavior of the galaxies, having existed long before Einstein ever generated his theories about them, reside in the Matter dimension of complexity. It is the methods of empirical science and predictions and measurements of behavior that allow the two domains of ontological theory and ontic reality to be coherently connected.

Correspondences between Big History and the ToK System

The broad parallels between the ToK System and Big History (BH) are likely apparent to BH scholars. Advocates of both systems emphasize the point that to understand humanity, we must place it in an emergent evolutionary context. In direct alignment with BH, the ToK System maps the universe on the axes of time (from past to present into the future) and complexity (from very simple elements present in the very earliest stages of the universe to increasingly complex entities, ultimately culminating in modern human societies). Moreover, both BH and the ToK System attempt to correspond the emergent domains of behavioral complexity in nature to the major areas of science (i.e., physics maps the most basic elements of nature, then chemistry, then biology, then the social or human sciences).

There is also significant alignment in the vision and values of both systems. In 2018, as the Executive Committee of the Theory of Knowledge (TOK) Society, we launched a conference series that sought to bring scholars together across the spectrum of academic knowledge and reflect on the "big" picture. Although the ToK System provides an anchor point for the TOK Society, it is also the case that we are interested in connections with other macro-level conceptions of knowledge and hence the broader name, "Theory of Knowledge," was used to denote our group. We embrace diversity of thought and the wide variety of different goals, perspectives, and topics that constitute the current academic structure. However, we also seek to anchor academic knowledge to a coherent overarching and organizing framework. In direct accordance with a primary mission of International Big History Association, the focus of the TOK Society centers on how the current fragmented pluralistic state of academic knowledge is problematic and might be reorganized into a more integrated pluralism. At the first TOK Society conference, scholars from philosophy, mathematics, biology, psychology, sociology, medicine and other disciplines offered perspectives that shared this goal and connected their visions to the Tree of Knowledge map of emergent evolution.

A second conference was held in April of 2019 that analyzed the ToK System in reference to the metaphysical and epistemological assumptions that shaped the Enlightenment thinkers and gave birth to the modern scientific enterprise. Consensus was achieved that the Enlightenment framework for science had produced a remarkably successful approach to the so-called "hard sciences," (e.g., physics, chemistry, biology). However, as E. O. Wilson (1998) notes in *Consilience: The Unity of Knowledge*, knowledge breaks down in its coherence as we move from biology into psychology and the social sciences. Consistent with the interdisciplinary, consilient vision of BH, there was consensus that the ToK System provides a new metaphysical and epistemological framework that can potentially bridge this divide. The TOK Society thereby embraces the challenge of coherently organizing the complex interrelationships among the natural sciences, psychology, and the social sciences, while additionally specifying the vision and place of the humanities as key contributors as well.

It is important to note that these academic analyses were done as we reflected on the current backdrop of cultural and political unrest. Specifically, we consider the current age of "tragic mass shootings, a deeply troubled educational system, a broken political system that lacks intellectual integrity and produces excessive polarization and a large disenchanted political 'center,' global threats to democracies and the general world order, dramatic increases in mortality rates due to drugs and suicide, and skyrocketing rates of anxiety and depression in our youth," to be well-characterized as an "Age of Confusion" (see Henriques, Kroger, Michalski, Quackenbush, & Schmidt, 2019). This sentiment and larger societal concerns align well with the vision of BH, and its concern with both academic and cultural fragmentation and the disordered state of knowledge.

In the inaugural issue of the *Journal of Big History*, David Christian (2017) spelled out his vision of the BH movement and argued that BH "aspires to a universal understanding of history" (p. 12) where we are trying "to link the findings of specialist scholarship into a larger unifying vision" (p. 13). The first explicit goal he identified was that BH would empower us with a greater understanding of who we are and our place in the cosmos. The second goal was to offer a vision of existence that is both universal and consilient. Third, BH emphasizes the need for interdisciplinary collaboration and doing so via an integrative reference point that is not just located on "the individual islands and continents of modern scholarship," (p. 14) but includes a big picture frame that supports the many links between them. Finally, with an eye toward the dialectic between the sciences and humanities, Christian emphasized the point that BH can provide an "origin story" for the modern age, one that is grounded in science and can help humanity understand our place in the cosmos and how we might use that to chart a course toward a wiser future.

In a highly similar fashion, the ToK System has also been framed to offer a universal origin story for humanity and its place in the cosmos on the dimensions of time and complexity. It is named the Tree of Knowledge both because it views the nature of the universe as having its fundamental root beginnings as a primordial seed or atom, out of which the whole has flowered forth. The name is also a reference to the need to connect to the "mythos" of the past and develop meaning–making systems for the present. The metaphor further embraces the idea that we need the scientific curiosity and moral clarity that allows us to eat heartily from the Tree of Knowledge, and we can flourish in doing so. Moreover, in direct alignment with Christian's (2018) articulation of a need for an "origin story," we believe that "scientific knowledge does have a story to tell about humanity, and it is crucial that we convey such knowledge in the context of a meaningful narrative that explicitly emphasizes a moral component. The ToK System is a picture of the universe story, as presently mapped out by scientific inquiry that potentially provides us with a shared origin myth" (Henriques, p. 259, 2011). And, via the "fifth joint point" (Henriques, 2011), the ToK also orients us to consider the future and reflect on what Big History scholars call the Threshold 9 Big History Singularity that might emerge in the upcoming decades (Korotayev, 2018).

Contrasts between the Big History Formulation and the ToK System

Perhaps the easiest way to characterize the central differences between BH and the ToK System is to begin by recognizing the disciplinary home of the two originators. Whereas Dave Christian is a historian who specialized in world history, Gregg Henriques is a clinical psychologist who specializes in theoretical and philosophical psychology. Both shared the perspective that macro-level frames and perspectives were needed to effectively organize their fields and to situate disciplinary findings in a larger picture of understanding. Paralleling Christian's desire to situate the place of modern human history in the larger and more universal historical context, Henriques also sought to ground the field of psychology in a larger context of understanding (Henriques, 2003). However, as he attempted to do so, he realized that there was a profound "problem of psychology" (Henriques, 2008). This is the name he gave to the fact that the field of psychology lacked any consensually agreed upon definition or shared understanding of its subject matter. The ToK System is a metaphysical conception of the universe that we believe solves the problem of psychology's missing definition and ill-defined subject matter. As we will describe later, it does this by clearly delineating the "mental" dimension of existence, or what Cahoone (2013) calls the mental "order of nature." By identifying the mental with the animal and by separating out human psychology from a more basic psychology that includes all mental/animal life, Henriques (2004) has argued that the ToK solves the problem of psychology and allows for a crisp definition of the field.

How the ToK functions to achieve this can be more clearly seen when we compare the ways BH and the ToK System divide the evolution of complexity. As noted, Big Historians use the term "thresholds" to describe the phases of emergent complexity. The eight thresholds include the following: 1) the Big Bang and Origins of Matter; 2) Stars and Galaxies; 3) Chemistry; 4) Earth and Solar System; 5) Life; 6) Homo Sapiens; 7)

Agriculture; and 8) Modern Technological Revolution (Christian, 2018). These thresholds correspond to the disciplines of cosmology and particle physics, stellar and planetary astronomy, chemistry, geology, biology, and then the social sciences and related disciplines, like anthropology, archaeology, and history proper. BH's thresholds roughly correspond to—but are also different in important ways from—the ToK System's four primary dimensions of existence: 1) Matter; 2) Life; 3) Mind; and 4) Culture. As shown in Figure 1, the BH thresholds 1 through 4 correspond to Matter on the ToK System (and the subject matter of the "physical/material sciences"), threshold 5 corresponds to Life (and subject matter of the "biological sciences"), and thresholds 6, 7, and 8 all correspond to Culture (and the subject matter of the "social sciences"). The difference between the eight thresholds and the four dimensions of existence is one key point of departure between the systems.

Noting the difference between the thresholds and the dimensions brings us to the second big difference between the ToK System and the Big History formulation. BH offers no identifiable place for the ontic domain of "Mind" and its corresponding science, what we call the "basic" science of psychology. The thresholds in BH jump from biology—which corresponds to the emergence of life approximately 3.8 billion years ago at threshold five—to the emergence of early modern humans studied by paleoanthropologists 250,000 years ago at threshold 6. At this point, the human social sciences (i.e., anthropology, archeology, history, sociology) become the prominent disciplines of inquiry. From our vantage point, this absence says more about the field of psychology than it does about BH scholars. The BH alignment provides a good illustration of how the boundaries of other disciplines (particle physics, chemistry, biology, even history) correspond to domains of inquiry that have at least vaguely identifiable boundaries. In contrast, as Henriques (2011) documents, psychology is a murky discipline that does not correspond to clear boundaries, but is vaguely positioned in the nebulous space between biology and the social sciences.

In the parlance of the ToK, basic psychology refers to "the mind, brain, and behavioral" sciences. Put simply, if we consider the mind to be what the brain does (as the cognitivists do) and consider what the brain does is to coordinate the behavior of the animal-as-a-whole (as neuroscientists and behaviorists do), then basic psychology can be considered the science of the mental order of nature as delineated by the diagram. This conception of the science of psychology lines up with neo-behaviorist and cognitive science visions and includes the behavior of all animals with complex adaptive bodies, from fruit flies to squid to elephants (see Godfrey-Smith, 2016). Importantly, it is the dimension of existence when sentience (i.e., the capacity to experience the world via feelings) emerges. In his article, *Psychology Defined*, Henriques (2004) points out why human psychology is appropriately considered a special subset of basic psychology. This is because humans enter the dimension of Culture through language and become self-reflective entities that justify their actions on the social stage. This makes human behavior qualitatively different from the behavior of other animals. It should be noted that one of the points of confusion, both for psychology and for larger understanding, is that although the field of psychology's basic concepts are anchored to the mental, the vast majority of modern day psychologists emphasize the human individual. Henriques (2004) argues that this animal versus human confusion and misalignment is part of the problem of psychology.

Another important distinction between the models pertains to the nature of complexity. BH generally characterizes complexity as being on a single axis, one that goes from particles to atoms to molecules to organisms to societies, with "threshold shifts" in between. Consider that in BH, the shift from particles and atoms that formed after the Big Bang into the stars reflects a threshold shift (i.e., from 1 to 2), as does the shift from chemistry to life (from 4 to 5). The ToK, however, recognizes two different kinds of emergence, one of which is "weak" and the other of which is "strong" (Clayton & Davies, 2008). Weak emergence happens within the context of a dimension of existence. For example, the new properties that appear when molecules form from the bonding of atoms are considered weakly emergent properties. Although these are important and warrant the term "emergent", they do not represent a qualitative shift in the kind of behavioral complexity observed in the strongly emergent transitions. We will delineate in more detail later what we mean by "qualitatively" and "strong emergence".

The Periodic Table of Behavior

		Dimensions of Complexity			
		MATTER	LIFE	MIND	CULTURE
		Physical	Biological	Psychological	Social
Object-Field Relations	Context of Behavior	Field	Ecology	Environment	Society
	Behavioral Entity	Object	Organism	Animal	Human Person
Three Primary Levels of Object Complexity (Part, Whole, Group)	Groups of Wholes	Molecule	Multicell/Colony	Family-Group	Family-Community-Nation
	Fundamental Whole	Atom	Cell	Mind-Brain System	Self-Consciousness System
	Fundamental Part	Particle	Gene	Neural Network	Symbolic Justification

Figure 2. The Periodic Table of Behavior.

One way that we have found helpful is to depict the map of complexity afforded by the ToK System in a "Periodic Table of Behavior." Behavior is defined here in the most general sense, which is change in object-field relations over time. Different dimensions show different kinds of behavioral change patterns. The Periodic Table of Behavior (PTB) explicitly splits the analysis of complexity into two separate axes, giving rise to a new way to organize and classify behavior patterns in nature. One axis (the columns) consists of the four dimensions depicted by the ToK (i.e., Matter, Life, Mind, and Culture). The other axis (the rows) consists of the level of object-change analysis that is being considered (i.e., part, whole, or group) within each of the dimensions. When these two axes are differentiated, a clearer picture of the various kinds of behaviors that exist in nature emerges.

The PTB makes a distinction between a "general level of object field relations" and the primary or foundational units, with the former being listed above the latter. The general level of analysis refers to the various kinds of entities associated with that dimension of complexity (i.e., object, organism, animal and person), and the fields which such objects reside (i.e., field, ecology, environment, society). For example, a physicist might track the behavior of either an apple or a cannonball traveling through the four dimensional grid (i.e., the three dimensions of space, one of time). Both apples and cannonballs are "general" rather than "primary" physical. The PTB asserts that there are fundamental or "primary" whole units. Atoms are the primary whole units that operate in the material dimension, with subatomic particles being the parts and molecular levels and above being groups or clusters. Cells are the primary units that operate in the living dimension, animals with brains are the primary units for the mental dimension, and human persons for the cultural dimension.

With the Periodic Table explicitly mapping behavioral complexity by differentiating the dimensions from the levels of analysis, we can now move to explain more clearly how the dimensions of existence are characterized in the language of the ToK. This division of complexity into the four different dimensions of existence is one of the most novel features of the ToK and is central to understanding the metaphysical and ontological claims it makes.

Matter: The First Dimension of Existence

The first dimension of existence on the ToK System is called Matter. The technical definition of matter in the physical sciences is a material entity that has mass and takes up space. However, Matter on the ToK refers to something broader, namely it refers to the emergence of the ENERGY-MATTER-SPACE-TIME grid that is sparked at the "big beginning," (Wood, 2018) which is normally described as the Big Bang. Wood (2018) offers a powerful articulation of this dimension, as he helpfully delineated each of these concepts with an acronym that captures the essence of it. For example, Wood characterized "TIME" as "The Initial Moment of Emergence" and "ENERGY" as the "Entropic Nexus Emitting Radiation, Galaxies, and You". Consistent with Wood's analysis and modern cosmology, the ToK posits that the material dimension of existence emerged at the Big Bang (what Wood calls the "Big Beginning") and has grown in space, time and behavioral complexity since. Figure 3 depicts the key features of this dimension of complexity.

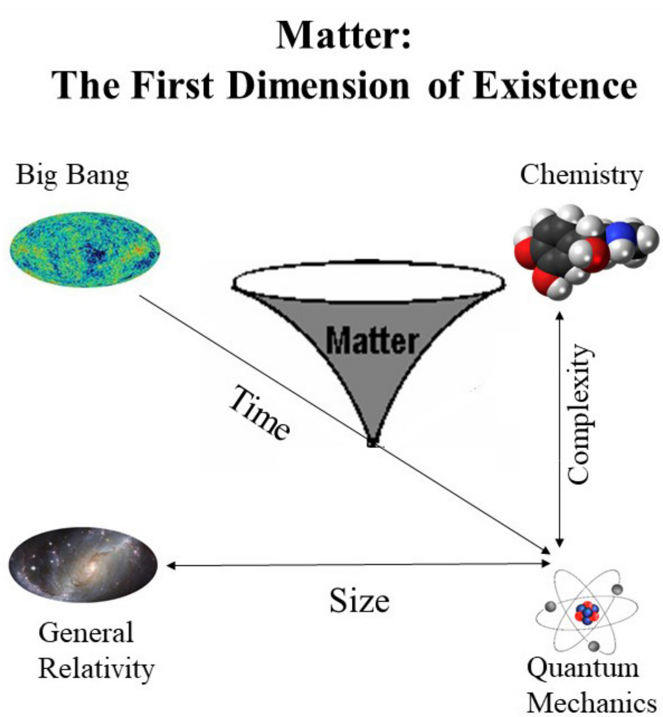

Figure 3. The Material Dimension of Existence.

A word is necessary about the concepts associated with the Big Bang, which, as Wood (2018) notes, can be confusing and need to be updated in the context of modern inflationary models. Modern physicists debate exactly how the universe sprang into being from the "singularity." In technical terms, the word singularity is derived from Einstein's theory of general relativity and refers to a gravitational force of infinite density, resulting in the inward collapse of the dimensions of space and time on a single point. It is important to recognize that it is a mathematical concept rather than an empirically grounded, natural science one. There is significant uncertainty among physicists regarding the nature of the singularity or single, atom-like point at the "Big Beginning". For example, there are deep questions about whether it should be thought of as energy or as matter or as some novel combination of the two or some other entity, such as a quantum fluctuation in the spacetime void. The laws and concepts of physics break down at this point, which makes things especially murky at a metaphysical level of understanding.

Consistent with several theoretical physicists (Das, 2017), the ToK System characterizes the initial condition as a "pure energy singularity." This places energy as the most fundamental substance, and the ultimate common denominator in the universe. It needs to be acknowledged that this conception bends the standard definition of energy in physics, which is defined as capacity to do work. There are many different forms of energy that are interchangeable (e.g., gravitational, electromagnetic), but energy most commonly refers to the amount of an entity, as opposed to an entity per se. In this regard, "pure energy" is somewhat akin to saying "pure quantity"; thus, it is important to realize that the concept being applied is not crystal clear. However, all foundational concepts reach a point at which they become difficult to define or conceptualize, and energy is no exception. At bottom, energy is simultaneously a ubiquitous and abstract concept. As the physicist Richard Feynman (1963/1995, p.71) wrote, "we have no knowledge of what energy [fundamentally] is."

The idea that energy is foundational, even relative to matter, is a conception shared by many esteemed physicists. Consider this quote from Stephen Hawking (1988), who was speaking about the emergence of elementary particles from the Big Bang: "*Where did [all the particles in the universe come from]? The answer is that, in quantum theory, particles can be created out of energy in the form of particle/antiparticle pairs*" We can also think about the equivalence between energy and matter, as represented in Einstein's famous $E = mc^2$ formulation. Consistent with this formulation, many physicists, including Einstein, argued that matter could be fruitfully considered as being a form of frozen energy. In short, the ToK depicts Matter as a dimension of complexity that emerges out of a pure energy singularity at the time of the Big Bang.

Despite some uncertainty regarding the ultimate substance of the singularity, there is much agreement about what emerged immediately after the inflationary period and hot Big Bang. Within the first second following the initiation of the Big Bang, the energy singularity had divided into the familiar forms of forces and elemental particles that we see today. These include the four fundamental forces in nature (i.e., the electromagnetic, gravitational, and strong and weak nuclear forces) and the elementary material particles (e.g., quarks, which make up protons and neutrons, and leptons, a familiar example of which is the electron). The Standard Model of Elementary Particle Physics forms the base of the Matter dimension on the ToK.

We are now on much firmer conceptual footing and have the key ingredients for a scientific understanding of the basic processes or behaviors of the universe. Such ingredients include objects (i.e., particles and waves), fields, and the force interactions that take place between them, as well as change processes that occur on the dimensions of space and time. From this, we proceed to track the emergence of increasingly complex material objects. Just as Christian (2018) delineates in *The Origin Story*, as the early universe aged, it cooled and expanded, and electrons (negatively charged particles) and protons (positively charged particles) formed into simple atoms, like hydrogen and helium. Then, large gas clouds formed, which then began to collapse in on themselves as a function of gravity. This collapse resulted in the formation of stars. As time progressed further, increasingly complex material objects emerged, including entities such as planets. In addition, atomic elements like carbon, nitrogen, oxygen, phosphorous and sulfur were formed in the bellies of stars and when the stars exploded, they were launched out into the universe and then found their way to the surface of planets. Very complex chemical molecules formed on the surface of planets that allowed for their emergence (i.e., environments that were neither too hot nor too cold).

This emergence is characterized by BH as four different thresholds, represented by particle physics, astronomy, chemistry and geology. The ToK System acknowledges these as different kinds of behavior patterns and require different scientific language systems to map them. The behavior of plate tectonics is, after all, different from the behavior of electrons. However, according to the ToK, they all exist at the material dimension of complexity and are mapped by the various physical sciences. Cosmologists map the behavior of the universe, along with other macro-level constellations like galaxies. Particle physicists map the behavior of subatomic entities like electrons. Chemists map the behavior of molecules, geologists the behavior of rock formations, and so forth. All of these are clustered together as the physical or material sciences precisely because they describe entities that behave at the Matter dimension. However, something *even more different* emerges when we shift into life. The biological sciences are not physical sciences. The reason, according to ToK metaphysics, is because "living" is a qualitatively different kind of behavioral pattern.

Life: The Second Dimension of Existence

The second dimension of existence on the ToK System is called Life. Although it is highly probable that life exists elsewhere in the universe, the ToK System maps our current knowledge of the empirically documented universe. The best scientific evidence suggests that planet earth formed approximately 4.5 billion years ago. Life, in the form of simple single cells, was present on earth by 3.7 billion years ago and may have started as early as 4 billion years ago (Lane, 2016). Exactly how life originated remains a bit of a mystery, although there are many clues and several plausible models.

Biologists have long debated exactly what constitutes life. Living entities have several unique features that inanimate objects generally do not have. These properties include behaviors such as metabolism, homeostasis, adaptive responsiveness to the environment, growth, and reproduction. In 1944, the physicist Erwin Schrödinger authored a now classic book directly asking the question *What is Life?* Schrödinger pointed out what is remarkable about life is how it is organized, how it takes energy in to perform work to fend off entropy, and how it appears to be self-organizing. Another way of saying this is that living objects are remarkably complex and work to effectively and efficiently maintain that complexity. According to the ToK System, the best way to think about Life is to consider it as an emergent dimension of behavioral complexity. The key concept that gives rise to a new dimension is found in semiotics (Pattee & Kull, 2009) and the interrelated concepts of sign translation, input-output information processing, computation, storage, communication and cybernetic feedback loops.

In the view provided by the ToK, the fundamental distinction between life and inanimate matter (particles, atoms, molecules, chunks of rocks, stars, etc.) is that the latter do not engage in *information processing* in the way that living organisms do. Information processing involves the following components: 1) inputs (data encoding), 2) data processing via computation, which includes storage and retrieval, 3) outputs (making changes based on inputs and computation), and 4) communication and feedback with other information processing units that 'speak the same language' (in this case, cell-cell communication). Information processing is crucial because, it gives rise to a separate dimension of causation. In chapter four of his book, Schrödinger stated that "living matter, while not eluding the "laws of physics" as established up to date, is likely to involve "other laws" hitherto unknown, which however, once they have been revealed, will form just as integral a part of science as the former". According to the ToK System, these "other laws" are to be found in the processes of biosemiotics (Pattee & Kull, 2009), self-organization (Kaufman, 1995), negentrophic physiological first principles (Torday, 2019), and genetic information processing (Bray, 2009) and the overlap and interconnections between them.

It should be noted that inanimate entities can be fruitfully couched in terms of information. Indeed, we support Ken Solis' (2018) argument that Big History can be effectively described in terms of the "unfolding of information" that started at Time = 1 Planck unit. The fact that physical systems can be framed in informational terms can also be seen in John Wheeler's phrase that we need to move "from it to bit" (Siegfried, 2000). However, when we are dealing with inanimate events, there are no data being processed, nor is there anything akin to an information processor, systematic computation, memory, outputs nor communication feedback systems that are tied to such processing occurring in inanimate objects or fields (Pattee & Kull, 2009). Although a bouncing ball can be described in physical information terms, it behaves the way it does because of the current forces acting on it; there are no inputs being computed or referenced against a store of information, followed by output and communication with other entities. Figure 4 depicts the central features that characterize the Life dimension of existence.

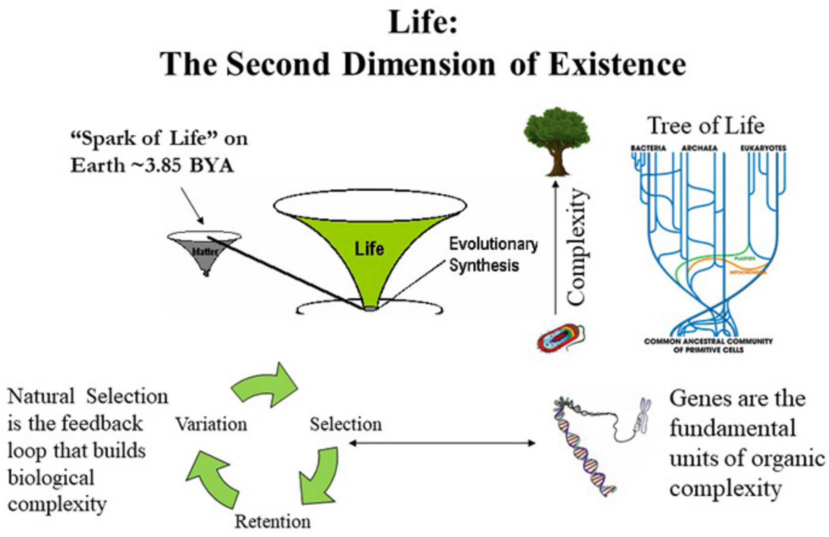

Figure 4. The Life Dimension of Existence.

In contrast to the inanimate world, life exists as a collection of information processing systems that have stored information across the generations and are shifting in response to ongoing experiences. As Dave Christian (2018, p. 79) put it, living organisms are "informavores" in that "they all consume information, the mechanisms they use for reading and responding" to their environments. This fact is present in the "language games" of biologists. Biologists speak of "the language of genetics" in that there are genetic messages, genetic software, and so forth. The famed DNA molecule is an information storage system, and the various RNA types (messenger, transfer, regulatory etc.) work as transformational entities that take the information encoded in the DNA and translate them to allow for the formation of proteins.

Many biologists have articulated in detail the utility of thinking about life in terms of information processing. In *Wetware: A Computer in Every Living Cell*, Bray (2009) articulated how the DNA and RNA complexes function as computational systems that give life its complexity. Farnsworth, Nelson and Gershenson (2012) go further and argue that the defining feature of life is information processing, and that it not only resides in the DNA and RNA molecular structure, but functional information processing is also woven together at all levels of life, from the genetic to the cellular to the ecological. They argue it is the central concept that allows biologist to understand the unique organized features and properties of living entities. The key point here is that living matter behaves qualitatively different from inanimate matter, and both the language of and properties associated with information processing are the root of this qualitative difference.

Genes can be considered the fundamental unit of information in the Life dimension of existence. The fundamental structural whole that allows the component parts to engage in information processing, along with metabolism, growth and reproduction, is the cell. As a fundamental unit, the cell is to Life what the atom is to Matter. For over a billion years, cellular life maintained a relatively basic structure (Lane, 2016). Then, at about 2 billion years ago, a massively important structural change happened when there was a remarkable jump in cellular complexity. That jump was the emergence of eukaryotic cells, meaning cells that had a nucleus contained in a membrane. Eukaryotic cells were a game changer in terms of behavioral complexity at the biological dimension. Such cells are much larger and far more structurally complex than simple cells like bacteria. Even more important, they set the stage for the emergence of multi-celled creatures, what Christian (2018) calls "Big Life," which is a "sub-threshold" in the BH system. Multi-celled creatures like plants exhibit many emergent properties that are not present in single-celled creatures. From a ToK perspective, the shift from cells to plants is similar in kind to the shift from atoms to molecules. The interaction of the parts does indeed create emergent properties. Although they are "higher up" on the Life cone in their degrees of behavioral complexity, plants and fungi remain at the dimension of Life because their behaviors are mediated by bio-information processing systems.

However, in one kingdom some multi-celled creatures did make a qualitative jump in behavioral complexity, and they did so in a manner that paralleled the shift that came with the emergence of life itself. Whereas the cell became a genetic information processing system that allowed for a new dimension of behavioral complexity, approximately a half–billion years ago a novel information processing system emerged that coordinated the multiplicity of cells. This resulted in a large organism that had the capacity to sense its environment, coordinate complex bodily movements, and respond to immediate feedback as a whole entity.

Mind: The Third Dimension of Existence

The third dimension of complexity on the ToK System is called "Mind." Mind is a term that has many different meanings in common parlance. It sometimes refers to thoughts or cognition, sometimes to sentience (the experience of subjective feelings) sometimes to self-awareness (reflection on feelings) and sometimes to observable actions (as in, "We saw him put his mind to that task"). Others equate it to the brain. In the ToK language system, when capitalized, "Mind" is like Matter, Life, and Culture in that it refers to an identifiable dimension of existence in nature. Whereas Matter corresponds to the behavior of objects, Life to the behavior of organisms, Mind corresponds to the behavior of animals, especially those with "complex adaptive bodies".

Figure 5 depicts the key defining features of Mind as the third dimension of existence on the ToK. It is arranged in a way that parallels the depictions offered for Matter and Life. The core logic for differentiating the behavior of animals with brains from other organisms (i.e., cells, plants, and fungi) is the same as the logic differentiating organisms from inanimate objects. The brain and neural networks are to an animal what DNA and genes are to a cell: a centralized, information relay and storage system. Just as genetic/epigenetic information processing networks link molecules together to form a qualitatively different dimension of complexity, brains link cells together to form an animal whole that can behave as singular units that exist in a higher dimension of complexity. Just as biosemiotics are required for understanding life (Pattee & Kull, 2009), cognitive neuroscience is the equivalent of a "neuro-semiotics" that is required for understanding the biological to psychological informational transition point (Tryon, 2016).

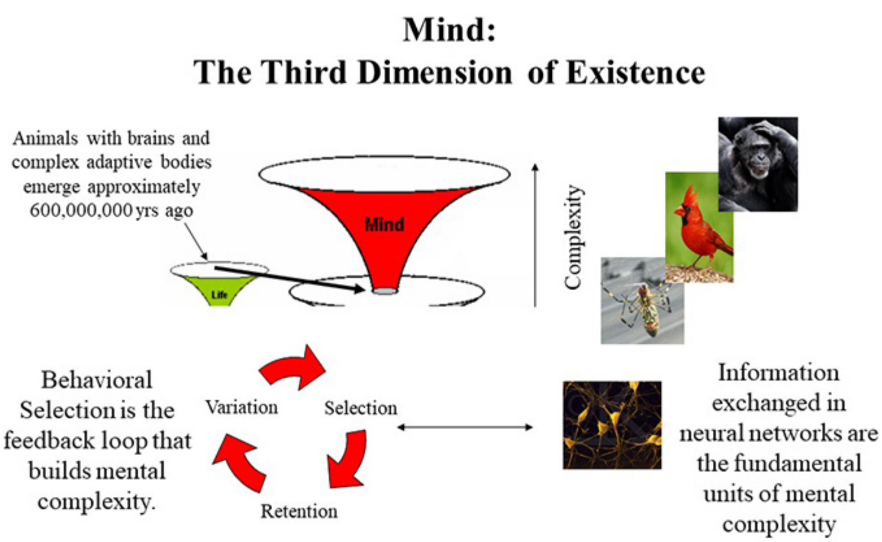

Figure 5. The Mind Dimension of Existence

Mind is a dimension that is central to psychology, for it is the dimension where all the basic (i.e., nonhuman) mental properties emerge. Specifically, as animals with brains evolved into increasingly complex forms, we see a flowering of new capacities, such as learning, feeling and thinking. Animals are multicellular creatures that move around in their environment. They are also heterotrophic, meaning that they rely on other organisms for their energy sources (i.e., they need to eat other organisms because they cannot transform the energy of the sun directly into workable forms). The elements of free movement combined with the requirement of finding and eating other organisms were the central forces that shaped the structure and function of the nervous system—the centralized information processing system that allows for the coordination of the behavior of the animal as a singular unit. The evidence for the earliest emergence of animals with the beginnings of a nervous system points to their appearance approximately 650 million years ago. Such animals were similar in form and function to modern day jellyfish. They did not have brains, but had only distributed neural networks.

As Christian (2018) notes, a remarkable transformation happened during the Cambrian Explosion approximately 550 million years ago. This is when animals with brains emerged and began to dominate the landscape. Often referred to as "the organ of behavior," the primary task of the nervous system in general and brain in particular is to guide the animal to approach energy sources that enhance survival and reproduction (i.e., prey, mates, enriching territories) and avoid sources that are destructive (i.e., predators, toxins, degraded territories). Explicitly drawing a clear dividing line between the behaviors of animals and other organisms is a key and novel feature of the ToK System. It highlights unequivocally that animals with brains represent a qualitatively different kind of entity.

Moving from invertebrates like worms and butterflies into vertebrates like fish and reptiles and finally into mammals and primates, we can see that there has been an evolution of the nervous system and mental behavioral complexity. The task of the basic psychological sciences (or the mind, brain, animal behavior sciences) is to map this dimension in all its complexity. The most basic of these phenomena include neuro-motor reflexes, and habituation and sensitization, the earliest forms of animal learning. Then there are more complex, instinctual fixed action patterns. Then operant behavior patterns emerge, ones that are much more flexible to being shaped by consequences. Presumably, this is where the earliest forms of consciousness or sentience emerged, as experiences of pleasure and pain guide animals toward and away from environmental stimuli (Godfrey-Smith, 2016). Then, more complex emotions and intimate social relations appear, including attachment and affiliation, status seeking, and complex problem-solving indicative of imaginative thought, and much more.

In sum, when capitalized, Mind refers to the third dimension of existence and consists of the set of mental behaviors. Mental behaviors correspond to the behavior of animals with a nervous system. The adjective mental refers to that which makes the behavior of animals so different from atoms and cells. In the ToK language system, mental behaviors are the proper subject matter of the basic science of psychology. However, ToK System also shows us that the behavior of people (represented by the dimension of Culture) is different from the behavior of animals. This straddling of two dimensions of existence (i.e., Mind/animal and Culture/person) is central to understanding psychology's problems with its subject matter. The behaviorists were primarily interested in animal behavior. This was in direct contrast with the introspectionists like Titchener, who argued that psychology's proper subject matter was human perceptual consciousness analyzed in the lab. The ToK argues that we need to split psychology into two domains, basic and human, with the former corresponding to animals in general and the latter to humans at the individual level. The relationship between the two domains can be clarified when we consider the following remark from Tolman in his 1937 APA Presidential Address, when he stated:

> [E]verything important in psychology (except such matters as the building up of a super-ego, that is everything save such matters as involve society and words) can be investigated in essence through the continued experimentation and theoretical analysis of the determiners of rat behavior at a choice point in a maze. (1938/1978, p. 364)

In other words, psychologists are interested in the drivers of animal behavior at its base, and, in addition, the field is concerned with human behavior at the individual level, which is distinctive from nonhuman animals because, as Tolman alludes, it takes place within a larger socio-linguistic context. This is why human psychology is so different from basic psychology, and it is to that context that we now turn.

Culture: The Fourth Dimension of Existence

The behavior of self-conscious people in socio-linguistic contexts resides in the dimension of existence called Culture on the ToK. The logic of why it is a separate dimension of existence parallels the argument given for the strong emergence of Life and Mind. Culture emerges because of a new semiotic system, human language. Human language is an open, symbolic syntactical information processing system that connects minds together to give rise to human societies. As Christian points out (2018), this is transformative in part because human language allows for collective learning, which is the sharing of information cheaply and effectively, and in a way that does not require direct experience. Although other animals have sophisticated systems of communication, human language is unique. It is an open communication system that includes learned symbols, grammatical syntax, and semantic meaning. Figure 6 offers a depiction of the dimension of Culture, which has clear parallels to the other dimensions of complexity.

The ToK System specifically characterizes Culture as large-scale systems of justification (Shaffer 2008). Justification systems refer to interlocking networks of linguistically represented beliefs and values that coordinate human action by framing both *what is* and *what ought to be*. As such, justification systems represent how shared beliefs and values functionally define, influence, and coordinate the human social field. Justification systems can range from the individual level (when a person talks privately to herself) to the dyadic level (a conversation) to the group level (e.g., as when preacher gives a Sunday sermon), and ultimately to the large-scale level of nations, political, or religious systems (e.g., the American legal system, a religion like Christianity, or the institution of science). The large-scale systems of justification are the essence of Culture in that they provide the macro-level contexts for justification. Such a formulation allows us to assert that the essential difference between a person and other animals stems from the former's capacity as an entity who deliberatively navigates the world of justification systems, both privately (to one's self) and publicly (to others).

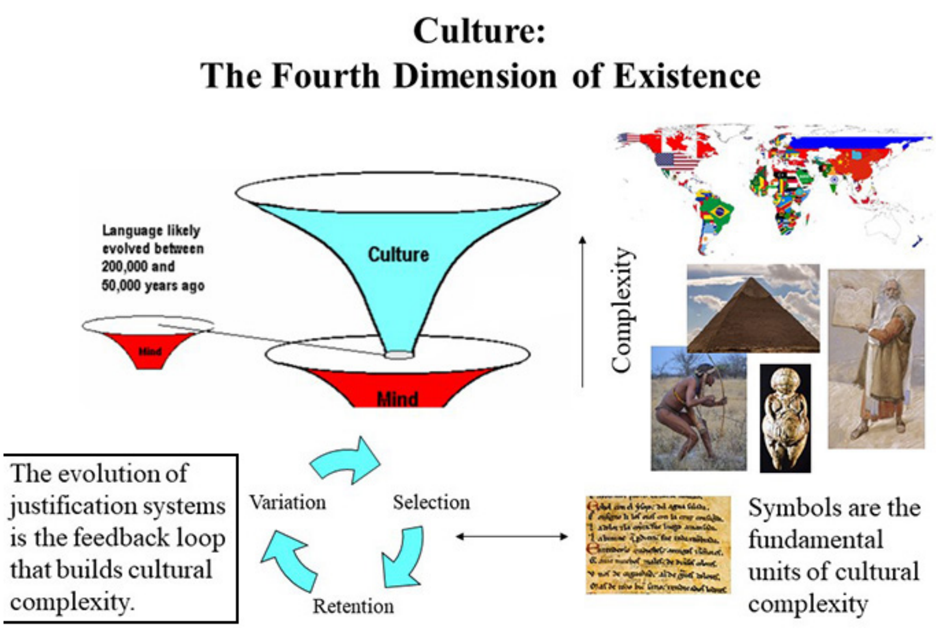

Figure 6. The Cultural Dimension of Existence

The ToK offers a clear perspective on the evolution of Culture. It posits that between 200,000 and 50,000 years ago a number of different forces converged to transform a fractured mimetic sign system (see Donald, 1991) of communication into an open language system that enabled full–throated "question and answer" dialogue. The ToK System posits that the linguistic capacity to ask questions resulted in a new and powerful evolutionary adaptive problem. This is called the problem of social justification, and it refers to explaining to others the reasons for one's actions. The ToK posits this created a tipping point and feedback loop that gave rise to the Cultural dimension of existence. Anyone who has raised a child knows that children first learn simple commands and descriptions for objects (e.g., no, mommy, juice). After they achieve some command of descriptive language, a transformation happens, usually around the age of two. This is when they start asking questions. Because there are many ways in which individual development replays evolutionary history, we can make the claim that there were periods of concrete descriptive language that then evolved into more abstract question and answer process. Why? Because, although questioning is relatively easy, answering questions raises a whole new series of problems. Spending time with an intelligent, curious four-year-old makes this clear: "Why don't we eat cookies before we eat dinner?"; "Why are you bald?"; "Why is the sky blue?" As such children readily demonstrate, asking questions is much easier than answering them. That is why exasperated parents eventually say: "That is just the way it is!"

Processes of social justification creates a shared social epistemology, which refers to the intersubjectively shared and linguistically mediated social construction of knowledge. It is characgterized as the "mythic" phase in human consciousness and culture by Merlin Donald (1991). We connect this to the insights of Berger and Luckman (1957), in their work, *The Social Construction of Reality*, in that the emergence of social epistemologies is central to what makes human consciousness and behavior so unique in the animal kingdom. Such cultural processes were likely in full force by 50,000 years ago.

It is important to note that the evolution systems of justification provides a clear reason as to what gave rise to the search for the transcendent. The explanation is that as people develop the capacity to ask "why" there is a need and longing to anchor the answers into larger meaning–making systems. The need to ground and embody such meaning–making systems likely is what drove the more recent construction of scare temples, like that found at Göbekli Tepe (Aslan, 2018). A brief summary of the sequence from there to modern history can now be traced. The Temples allow for the alignment of investment practices, technology and meaning making. They require more centralized ways of being and that gives rise to the need for agriculture. That creates more centralized and complex social arrangements, and this necessitates more sophisticated record keeping. This drives the emergence of writing. Writing is external memory and marks the beginning of the shift from pre-modern mythic to modern Culture. An important reason for the transition is that writing sets the stage for systematic quantification, external memory and formal "history".

Twenty-five hundred years ago, there was a general large-scale emergence of what we consider to be more "formal" systems of justification. Such systems likely relate to the appearance of writing and elite literacy. Labeled by some the Axial Age (Eisenstadt, 1986), formal justification systems that we can label "philosophy" begin to emerge at various places in both the East and West during this period. In the ancient Western intellectual tradition, Socrates builds off the work of the Pythagoreans and others and gives birth to formal modes of epistemological inquiry. Via systematic questioning likely with mathematics as the ideal representation of authentic knowledge, Socrates realizes that social epistemology is (potentially) vacuous, hence his famous claim that he is wise only in the sense that he knows that he knows virtually nothing. Plato and Aristotle take up the mantle to develop formal-analytical philosophies that withstand Socratic-like philosophical criticism. This is the beginning of formal, refined academic knowledge as separate from commonsense social epistemology (at least in the West). In the 15^{th} and 16^{th} centuries, natural philosophy grew into modern science. The reliance on empirical methods and the mathematical mapping of matter in motion as achieved by Newton gives rise to the Enlightenment dream of purely rational justification. This gives rise to the modern institution of science, which has evolved out of Culture and functions to map the Big History of the universe and our place in it.

The Fifth Joint Point, the Singularity, and the Future of Humanity

As Korotayev (2018) notes, a number of futurists and scholars associated with Big History have noted a striking pattern associated with the acceleration of complexity over time. Made perhaps most well-known by Ray Kurzweil's (2005) *The Singularity is Near*, the acceleration is such that it provides a clear "Singularity Hypothesis" in the Big History landscape, and a number of scholars have argued that "Big History Threshold 9" should appear between 2027 and 2045. Offering an in–depth review of several similar models of the accelerating evolution of complexity, Korotayev (2018) concludes that there are significant data "to indicate the existence of sufficiently rigorous global macroevolutionary regularities (describing the evolution of complexity on our planet for a few billion of years), which can be surprisingly accurately described by extremely simple mathematical functions." However, he does not believe that this "singularity" event will be necessarily transformative. Rather, he believes there are more reasonable interpretations that frame "this point as an indication of an inflection point, after which the pace of global evolution will begin to slow down systematically in the long term".

The ToK offers an interesting perspective on the concept of a "singularity" appearing in the relatively near future. We can start by noting that the ToK includes the insight regarding the accelerating pace of complexity and change. What it suggests, further, is a way to frame it. Specifically, the ToK suggests the possibility of the emergence of a new dimension of existence in a way that overlaps with the timeframe specified by Korotayev (2018). The ToK posits that novel dimensions of existence occur when new information processing or semiotic systems emerge and then become networked together and regulated via a centralized control system. These transitions are called "joint points" in the ToK language system, and the ToK identifies joint points between Energy and Matter, Matter and Life, Life and Mind, and Mind and Culture (Henriques, 2011).

As noted, each dimension of existence following Matter has been associated with a new "semiotic" system (e.g., genetics, neuronal information processing, human language). Based on this logic, we can ask: Are we seeing the emergence of novel information processing systems and have they become networked together in a centralized way? There are some obvious technologies that present themselves in a way that results in us answering in the affirmative. Computers, the internet, and the interface between human and artificial intelligence systems are highly suggestive of an answer that might be "yes".

In accordance with predictions made by the futurist philosopher Oliver Reiser over fifty years ago (in 1958), there does appear to be a "world sensorium" that is emerging based on new information processing, and this is, perhaps, a reasonable interpretation of the singularity that has been identified by so many futurists. In the language of the ToK, this is known as "the fifth joint point" (Henriques, 2011). It is the possibility that we are on the cusp of a new emergence, that of a meta-modern, Meta-Cultural dimension of existence.

The ultimate vision we embrace is that we need to wisely merge our knowledge of the cosmos and our world, our human natures, and the nature of human societies, and emergent technologies and artificial intelligences with foundational, universal values that enable core considerations regarding human dignity, well-being and integrity. Put another way, with its scientific humanistic philosophy, the ToK System orients us toward the crucial question: Given the remarkable pace of change in our world, can we foster the growth of environments and ways of being that enhance dignity and well-being with integrity? (Henriques, 2011).

Conclusion

In sum, the ToK System represents a new map of cosmic evolution. Consistent with many models that adopt a Big History (e.g., Chaisson, 2005) or related emergent naturalistic perspectives (e.g., Cahoone, 2013), the ToK System depicts the grandeur of cosmic evolution on the dimensions of time and complexity.

What makes the ToK unique, however, is that it explicitly characterizes the universe as an unfolding wave of energy and information that has produced four distinguishable dimensions of existence, defined as Matter, Life, Mind, and Culture. The latter three dimensions of behavioral complexity are explained as the emergent functional consequences of distinct semiotic or information processing systems (i.e., genetic, neuronal, and linguistic).

The similarities and differences between the BH movement and the ToK afford scholars many interesting points of analysis. Most obviously, the correspondence and relation between the eight thresholds of BH and the dimensions of existence on the ToK warrants deep consideration. In particular, the ToK suggests that a threshold titled "Mind" should be added between Big Life and the appearance of humans. Finally, it should be noted with encouragement that both BH and the ToK situate humans in the cosmos in an effort to foster greater understanding of the past with the goal of charting a wiser course in the future. Given the current state of confusion and fragmented pluralism, it is affirming to see this convergence of viewpoints.

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Beachcombing and Coastal Settlement: The Long Migration from South Africa to Patagonia—The Greatest Journey Ever Made

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Abstract

Although studies of prehistoric human migration now run into the hundreds, a single, chronological narrative of the peopling of the planet has not yet been presented, Most studies have been produced by specialists of a region. The need for a specific migration narrative—highlighting a primary migration route—is desirable for a coherent big-history understanding of how prehistoric *Homo sapiens* peopled the planet. Assembling the existing research, we follow the primary migration route from South Africa to Patagonia—a coastal trek up the coast of Africa, along the shores of the Indian Ocean followed by a circum-oceanic trek around the entire Pacific Ocean., the whole journey, with settlements established along the way, occurring over a period of 60,000 up to 115,000 years. From South Africa, now recognized as the refuge of early *Homo sapiens*, migration can be traced through human fossils, cave occupations, camp and work sites, shell middens, animal remains, and tool remnants. To these, genetics has added the identification of genetic markers for more accurate route determination. This coastal migration route incorporates recent archeological reassessments that have confirmed (1) the "Southern Dispersal" route out of Africa to coastal South Asia; (2) a 10,000 to 15,000 thousand year "Beringian Standstill" during the last glacial maximum; and (3) a primary "Coastal Route" down the west coast of the Americas. From this primary coastal migration route, hundreds of rivers provide resource-rich entrances into continental interiors while ocean reaches beckoned to the adventurous, thus clarifying the earliest stages of the peopling of the Earth.

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> The coastal route would be a sort of prehistoric superhighway, allowing a high degree of mobility without requiring complex adaptations to new environments that would be necessary on an inland route. . . . because of the ease of movement afforded by the coast, the line of sandy highway circumnavigating the continents, this would allow relatively rapid migrations. No mountain ranges or great deserts to cross, no need to develop new toolkits or protective clothing, and no drastic fluctuations in food availability.
>
> – Spenser Wells, *The Journey of Man* (2002)

Prologue

My junior high school world history textbook began with chapters on the Egyptians and Greeks, but in so doing, it left me puzzled. What had happened over tens of thousands or even millions of years since primitive ancestors of humans had roamed African jungles? In 1956 there were few clues to the prehistoric past of humans, but I had heard about a South African skull—the Taung skull, I learned much later—found in 1924 by Raymond Dart that he had named *Australopithecus africanus*—defined as "the Man-ape of South Africa." This empty stretch of time in the prehistory of humans persisted for a long time, and my perusal of works like H. G. Wells' *Outline of History* (1920), revised up until the end of World War II, did not satisfy the question. The earliest historically precise date Wells could provide was 776 BCE, derived from a Greek text that listed the winners that year in the Olympic Games. Events of earlier times were narrated in the the *Iliad*, the *Odyssey*, the Old Testament, and the *Epic of Gilgamesh*, though one hardly felt like any of these could be regarded as factual history.

Through the decades after high school, I watched for details on the African origin story. In the quarter century after Dart's South African discovery, it was given little attention because of a general resistance to the idea of Africa as the homeland of *Homo sapiens*. There were several rivals that predated it. A skull found on the island of Java (1891-1892) known as Java Man pointed to an Asian origin, as did the discovery of ancient human remains in Zhoukoutien Cave near Peking, now Beijing (1923-1927), known as Peking Man, and predating both, the discovery of remains known as Neanderthal Man (1856) named for the Neander Valley in Germany where they were unearthed. The prevailing Eurocentric view of the early 20th century was enhanced by the discovery in England of a carefully contrived hoax known as Piltdown Man (1912). Neglect of the African-origin theory continued until the Piltdown skull was exposed as an elaborate fabrication in 1953. Soon thereafter, Robert Ardrey's *African Genesis* (1961), which I read immediately following its publication, brought Dart's Taung skull into focus, clarified its importance, and explained the delay in recognizing its importance: "no fossil background for Dart's creature had ever been found in all Africa."

But Dart's claim (1925) that "the specimen . . . exhibits an extinct race of apes intermediate between living anthropoids and man" still proved too challenging for the European anthropological establishment, let alone the general public. A Eurocentric bias meant an African origin for modern humans was beyond imagining.

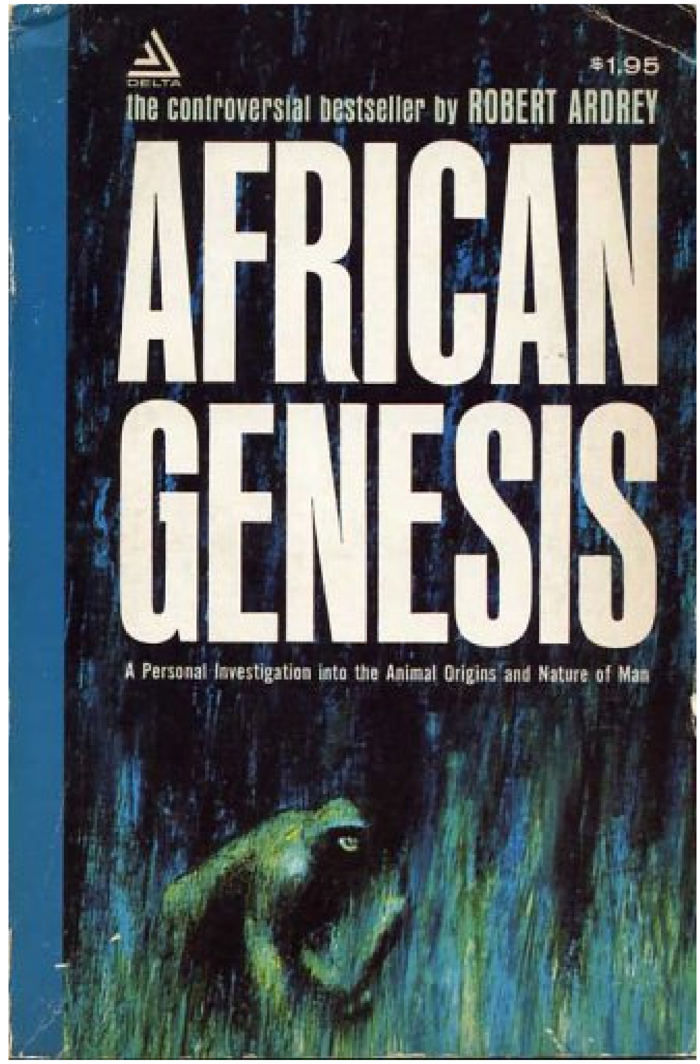

Fig. 1. Robert Ardrey's *African Genesis* (1961) provided the first full treatment of human origins in Africa. The book was a remarkable piece of hobby journalism from a playwright, Hollywood screen writer, and actor on the Broadway stage. Ardrey followed this book with another highly readable contribution in anthropology, *The Territorial Imperative* (1966). Image source: www.amazon.com.

Accumulating Evidence for an African Origin

African Genesis marked the beginning of a new dawn for anthropological theory. The next quarter century turned up multiple verifications from East and Central Africa. The best known was Donald Johanson's 1974 discovery at Hadar in Ethiopia of a 3.2 million year old hominin, *Australopithecus africanus*, more commonly known as "Lucy." Three years later, Mary Leaky uncovered three sets of *A. africanus* footprints at Laotoli in the Olduvai Gorge. These were made by two adults walking together step by step, perhaps holding hands, and a meandering child—the three providing a brief glimpse into prehistoric family life. The footprints were made in volcanic ash turned to rock dating to 3.7 million years of age. As Raichlen *et al* (2010) have noted, the Laotoli footprints are now recognized as our "earliest direct evidence of human-like bipedal biomechanics." There were other dramatic discoveries, of course, enough to remove all doubts concerning the prehistory of humans in Africa and to piece together a tentative prehistory of *Homo sapiens*.

A visual answer to my long standing high school question took shape when I opened my October 1988 issue of *National Geographic* where fragmentary glimpses coalesced in a map of "the peopling of the Earth" (Fig. 2). Its striking answer was captured in arrows out of Africa tracing human migrations to Australia, Asia, Europe, and eventually the Americas.

Dates in thousands of years at various points on the map—96,000 in South Africa, 50,000 in Australia, 33,000 in Europe, 12,000 in North America—plotted the progress of humans in their movement across a prehistoric landscape of six continents. Distinctions we recognize today had not yet been worked out: the map mixed much earlier migrations of *Homo erectus* with the much later migration of *Homo sapiens*; moreover, generalized arrows raised more questions. The arrow from Africa to Australia passed through Israel, crossed over the Himalayas, then leaped from land to water at Myanmar and followed a water route through the Strait of Malacca, with a final jump from the Indonesian island of Java to Australia. As Nicholas Wade (2006, 76) remarks of these early migration maps, "the arrows unavoidably give the impression that the emigrants were purposely traveling to these distant endpoints. . . . In fact, it's doubtful that they were on a journey at all." But movement through the Americas was equally schematic—simplified to an arrow from Alaska through the center of Canada and the American Great Plains to Central and South America. Arrows traversing enormous spans of the Pacific Ocean raised questions of watercraft, especially since *Kon-Tiki* (1948), Thor Heyerdahl's bestseller account of a Pacific Ocean crossing on a raft, had suggested Pacific colonization from South America, but Heyerdahl's theory did not fit the evidence and was absent from the *National Geographic* article. Firm evidence was limited to a scattering of excavation sites from which generalized migration routes were inferred, but details of prehistoric life in Africa or during their subsequent migration were missing.

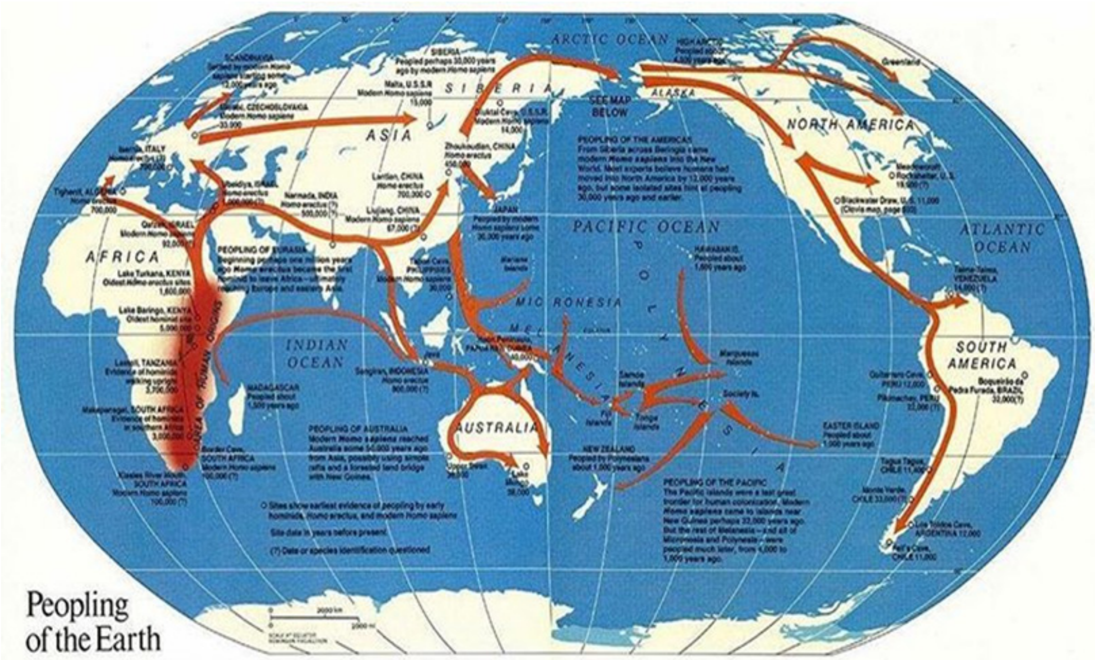

Fig. 2. An early map of prehistoric human migration from "The Peopling of the Earth" issue of *National Geographic*, October 1988. Note the generalized migration routes which are dependent on a limited number of fossil sites. Image source: www.natgeo.com.

Since early in the millennium, Africa as the homeland of modern humans has been settled science with 80,000 BP an approximate date for their departure (Oppenheimer 2003). Dozens of books and thousands of articles over the past half century have followed discoveries of hominid fossils, cave occupations, stone age tools, and prehistoric worksites. Paleoclimatology has clarified regional occupation at different times and genetic analysis has established relationships between human populations across Africa and beyond. Much of this information remains unknown, though an African genesis for anatomically modern humans is solid enough to know that this is where the human journey began. As Armitage *et al* (2011) and others have detailed, the evidence is substantial and the primary coastal route out of Africa well established. Many details of this journey are piecemeal with evidence from multiple regions of every other habitable continent. The routes that humans followed in the peopling of the world have been refined, are generally understood, and can be guessed by connecting the dots—linking each archeological site to the next, though the vast interior regions of Africa, Asia, and Europe offer too many "nexts." The result is a complex web of possibilities, with many missing details inviting guesswork. Despite a continuing vagueness of detail, by the end of the century Africa had been identified as the indisputable "cradle of modern humans" (Lewin 1987a).

The South African Incubation

The ideal of a unified narrative, dependent on a clearly defined migration route is valuable and essential for a coherent big-history understanding of how prehistoric *Homo sapiens* spread around the world. As the Prologue to this paper indicates, this question has engaged my attention for more than six decades. The paper itself was suggested by the title of a book reviewed elsewhere in this issue of *JBH*, *Trekking the Shore* (2011), which treats "the shore" in separate essays on human use of marine resources at twenty separate locations but fails to assemble them into a coherent "trekking" narrative. The volume relies on evidence from widely separated locations and thus depends on discovery and excavation by specialists who are expert on specific regions.

In contrast, this paper singles out the primary migration route by assembling the existing research on the primary migration route from South Africa—a route up the coast of East Africa, along the shores of the Indian Ocean, followed by a circum-oceanic trek around the entire Pacific Ocean that ended in Patagonia. This narrative has emerged because terrestrial food sources vary from plentiful to non-existent whereas marine foods are the most reliable of environmental resources from the tropics to the coldest regions of the Arctic.

Of primary importance for this narrative is establishing the departure point of this migration. Most of the discoveries of prehistoric hominid fossils, with the except of the Taung skull, were unearthed in East Central Africa: Louis Leaky's 1.75 million year old *Australopithecus* find, and the discoveries already mentioned by Donald Johanson and Mary Leakey. By the early 1990s, the theory of an African origin was secure. But while very ancient fossils of earlier species had turned up in East Central Africa, *Homo sapiens* fossils from this region were rare, though they were evident elsewhere. A recent discovery on the Atlantic coast of Morocco (Hublin *et al* 2017) has revealed that anatomically modern humans had expanded far beyond the original discovery region of East Central Africa. When conditions were favorable, it appears that early modern humans had possibly occupied much of the continent. Another discovery emerged from the Morocco site: a divergence of *Homo sapiens* as a separate species appears to have occurred as early as 350,000 to 260,000 years ago, much earlier than the 200,000 years that has been long assumed as a beginning date.

After 200,000 BP, however, and for the next 75,000 years there is little evidence of a *Homo sapiens* presence in western, northern, or eastern Africa. Petit *et al* (1999) have shown that the period known as

Glacial Marine Isotope Stage 6 (MIS6), dated from pollen and plankton remains in seafloor sediment cores as lasting from 195,000 to 125,000 BP, was one of the longest and coldest periods of the Quaternary. Under these conditions, as geophysicist Robert Walter *et al* (2000) have pointed out, lower rainfall shifts forested regions toward a savannah landscape, or even steppe if dry seasons are extended. Walter's region of interest was Eritrea on the African coast of the Red Sea, but his observations apply to the whole of East Africa. Throughout this period most of the continent could not provide supportive floral and faunal resources for human habitation. Some isolated refuges may have harbored small groups for a time until they moved or succumbed to extinction. Successful groups were those that gravitated toward the narrow edge of the savannah adjacent to coasts where they could exploit marine food sources.

Evidence comes from occupation sites and artifacts along the southern coast of Africa. As the Taung skull dating indicates, ancestral species were present in South Africa for more than a million years. Recently Schlebush, *et al* (2017) have drawn attention to the South African coastal region as a habitat of central importance in the narrative of modern human emergence where numerous caves show evidence of more congenial living conditions and extended human occupation. By the time *Homo sapiens* emerged 350,000 to 200,000 BP they had acquired a pan-African gene pool of great diversity from earlier species over at least two or three million years. Surprisingly, though, the genome of modern humans outside Africa has a comparatively low genetic diversity, suggesting that the modern non-African human lineage was squeezed through a genetic bottleneck. A limited population—a regionally focused breeding group from which peripheral diversity had been snipped away by territorial concentration—appears to have formed the founding population of subsequent *Homo sapiens* outside Africa. Anthropologists and geneticists (Fagundes *et al* 2007; Gonder *et al* 2007; Benhar *et al* 2008) have described and dated this bottleneck within the Glacial Marine Isotope Stage 6, thus placing it within the period of the South African habitation.

The unique ecosystem of South Africa, specifically the Cape Floral Region (CFR), is the key to its importance. The CFR is one of the richest and most congenial environments where the major population of *Homo sapiens* dwelled throughout Marine Isotope Stage 6, thus providing an extended incubation for acquisition and development of survival skills both physical and cognitive. The region occupies an area roughly 200 by 400 kilometers for an official area of 78,555 km^2 (31,000 ml^2); it is one of two hotspot Floral Kingdoms on the planet, so rich in plant species that it is today one of the Global 200 priority ecosystem conservation regions, designated a UNESCO World Heritage Site in 2004. With valleys, hills, and mountainous variations in elevation, it includes three climate regions, thousands of floral species, and a rich array of shorebirds and mammals.

This ecosystem provided numerous edible roots, tubers, bulbs, and corms (geophytes); appropriately, anthropologist Curtis Marean (2012) has described it as "a coastal cornucopia." Important for our story are the numerous rock shelters and caves along the coast, some with spectacular views of the Indian Ocean. Here we find evidence of occupation extending to ancestral hominin species as well as occupation by *Homo sapiens* extending from 200,000 BP with access to diverse seafood resources. The total population of this region may have remained below 10,000; the range of population possibilities calculated by Fagundes *et al* (2007) indicates that population may have fallen as low as 600, a marginal number for any species, which suggests *Homo sapiens* could well have gone the way of a dozen earlier extinct hominin species.

Despite climate and environmental confinement to the region, the evidence of survival strategy and cognitive advance from this population is rather remarkable. Nuno Bicho *et al* (2011, xix) have noted that "coastal food sources are rarely transported more than 10 km [6 miles] from the shore and most of the evidence [in South Africa] has accumulated within

Fig. 3. The Cape Floral Region of South Africa, noted for exceptional temperate biodiversity, is home to 9000 species of plants, sixty percent of which are endemic to the region. The coast is populated with five tortoise species specific to the region, along with seals, seabirds, penguins, and antelope. Human occupation in more than twenty caves extends through the entire 200-thousand-year history of *Homo sapiens*. Image source: whc.unenesco.org.

2-4 km." In the Cape Floral Region, more than two dozen caves or cave complexes within this range provide systematic records of human occupation, culture, technology, and harvesting of seafood. A complex mix of cultural achievements emerged here: various kinds of stone cutting tools, bone implements, and the beginnings of personal decoration in the form of pierced shells, obviously for stringing into beads. Tools have been found at inland sites such as Cooper's Cave (Berger 2003). Fragments of engraved ostrich egg water containers dating from 65,000 to 55,000 years ago have been found at Diepkloof Rock Shelter. Pierre-Jean Texier (2010) who made the discovery, notes that the engravings seem to be made for display, perhaps indicating a communal connection, and were hardy enough to serve as canteens while away from a water source. Brown *et al* (2009) have deciphered the technology that employed fire to harden rock for tool making at Pinnacle Point, a technology evident from 195,000 to 90,000 BP. These and other practical and decorative innovations may be considered proxies for an upsurge in *Homo sapiens* linguistic, symbolic, and cognitive competence.

When extensive cave art in Europe was discovered in Europe at Altamira and Lascaux, it was considered evidence for a leap in cognitive ability around 40,000 BP, perhaps stimulated by the challenges of the Ice Age, that accounted for the foundational skills of modern civilization and culture—and perhaps the dominance of *Homo sapiens* over Neanderthals that led to their extinction around that time. This emphasis appears, too, in *The Roots of Civilization* (1972), Alexander Marshack's extensive analysis of engraved bones, and his concept of "cognitive archaeology" whereby ancient artifacts are examined as proxies for cognitive development. As rich and suggestive as these observations were, the artistic, decorative, and technological accomplishments in South Africa suggest that a leap in human cognition and imaginative skills occurred more than 100,000 years earlier.

Seafood harvesting by occupants of Klasies River Caves (Thackeray 1988) and Pinnacle Point cave 13B (Marean 2007, 2011) suggest a dietary explanation for this upsurge: nutritional anthropologists have argued that continual harvesting of seafood during Glacial Marine Isotope Stage 6 points to seafood and shellfish as providing fatty acids not produced by the human body that are nevertheless instrumental for brain development (Cunnane *et al*, 1993; Crawford *et al.* 1998; Broadhurst *et al.* 2002). Long-term harvesting of seafood over a period of at least 70,000 years may have provided the nutritional stimulus instrumental in the dramatic development of cognition that characterizes humans during subsequent migrations that required multiple adaptations as they moved on to people the planet.

Alongside recognition of South Africa as a nutritionally rich incubation region for early *Homo sapiens*, studies of mitochondrial DNA (mtDNA), a marker unique to female genealogy, have verified a South African departure for humans as they set out to explore the world (Lewin 1987b). Rebecca Cann *et al* (1987) have shown that the entire human family traced to an ancestral "lucky mother" (popularized as "Mitochondrial Eve") who lived somewhere in sub-Saharan Africa. Recent calibration of ancient mitochondrial genomes by Fu *et al* (2013) suggest her date as around 160,000 BP. Within her line, Haplogroup LI/L0 successively gave rise to L2 and L3 around 80,000 BP, all "rooted deeply in sub-Saharan Africa with derivative branches outside" (Oppenheimer 2012). Atkinson *et al.* (2008, 2009) identify the Horn of Africa as the later origination point for the L3 haplotype, the source of the derived M and N genetic branches found in all non-Africans: Carbon dating indicates M and N originated between 69,000 and 50,000 BP. Numerous lines of inference verify this range of dates.

Trekking Out of Africa

A warming climate that began as Glacial Marine Isotope Stage 6 came to an end undoubtedly opened a path for movement of humans north from South Africa. Possible departure points from long-occupied caves stretching along more than 400 km (240 m) of South African coastline would lead logically to numerous inland migration routes. However, the barrens of the Sahara desert would curtail or redirect some, though a route through the lake district of the north-running Rift Valley would provide an unobstructed passage to the north. Here, too, as Broadhurst (1998) has shown, Rift Valley lake fish and shell fish would provide similar nutritional benefits for cognitive development as marine seafood on the South African coast. Passage to the Nile River Valley would follow, leading ultimately to the coast of the Mediterranean.

The earliest movement of *Homo sapiens* out of Africa appears to have occurred from the Nile Valley, perhaps from the river delta. Dated fossil remains in Israel show that a small group from what is now northern Egypt headed northeast, but evidently advanced no farther than Skhul Cave on the slopes of Mount Carmel (Wells 2006, 116-117). Evidence of occupancy here and at Qafzeh dates from 110,000 BP. Steven Olson (2002, 75) maps a probable route across Sinai and north into Israel that suggests the Nile Valley as the most likely approach from the south. However, evidence of this early migration extends no farther than Israel. The size of this group cannot be determined. It was evidently numerous enough to leave a record over several millennia, but it declined, eventually becoming too small to sustain itself and had gone extinct by 70,000 BP and thus represents a backwater migration of little interest for the peopling of the world.

More than a hundred millennia of South African coastal living with a sustaining diet of seafood provides an explanation for human occupation long after some migrating groups left. However, adventuring should never be forgotten: unforced migration northward on the warmer east coast of the continent was virtually inevitable. Many years ago, Carl O. Sauer (1962) suggested that African seashores would provide the best environment for primitive humans—free of the vagaries of inland climate variations and rich in seafood resources. Spenser Wells, author of *The Journey of Man* (2002) and narrator of the related video, made the case for coastal migration: "The coastal route would be a sort of prehistoric superhighway, allowing a high degree of mobility without requiring complex adaptations to new environments that would be necessary on an inland route." While this was written from an understanding of coastal Africa, it applies to regions far beyond: "because of the ease of movement afforded by the coast, the line of sandy highway circumnavigating the continents, this would allow relatively rapid migrations. No mountain ranges or great deserts to cross, no need to develop new toolkits or protective clothing, and no drastic fluctuations in food availability" (Wells 2002, 69).

Conceivably a number of migratory groups may have followed the east coast of Africa with continual access to seafood encouraging short term settlement along the way. Such migrations would rely on experience from millennia of seafood harvesting on the southern cape. Despite the ease of this coastal "superhighway," progress might well have been unhurried with the establishment of a string of temporary coastal settlements, though this remains conjecture without specific material evidence. It is unlikely that coastal migrants would have entirely foregone floral foods and geophytes available within a few kilometers of the coast, but the abundance and reliability of seafood resources would favor beachcombing and some semi-permanent coastal settlement. This coastal route would be limited to a narrow corridor defined by these alternate sources of food. Despite this limitation, traces of migration are still unlikely and in fact have escaped discovery; as Nuno Bicho *et al*. (2011, xv) point out, ancient shorelines have been inundated by rising seas brought on by post-glacial climate warming. Evidence in the form of tools, firepits, or middens may have existed on prehistoric beaches, but they are now as much as 100 meters underwater.

While material evidence of east coast African migration is lacking, recent genetic evidence has surfaced. In a survey of foragers, farmers, and herdsmen from South Africa, Malawi, and Kenya who lived between 400 and 3,100 years ago, Pontus Skoglund *et al* (2017) have turned up evidence of a very ancient, "hitherto unknown" pre-agricultural cluster of "hunter-gatherer populations stretching from Ethiopia to South Africa." David Reich, one of the investigators of the Skoglund study, refers to them as a "ghost population" of foragers that once dominated the east coast of sub-Saharan Africa, referring to them as "East African Foragers" (Reich 2018, 221). The study establishes that they show closer relationship to non-Africans than to any population group within Africa. This ghost population, which was itself a complex mix of forager groups, may well be (or may be related to) the East African migrant foragers who found their way out of the South African Floral Region and whose descendants eventually migrated out of Africa.

An east African coastal route is evidenced beyond the Horn of Africa where early modern humans crossed the span of water between Africa and the Arabian peninsula at *Bab-el Mandab*, the "Gate of Grief." These migrants carried the deeply rooted female-bearer mitochondrial DNA (mtDNA) and male-bearer Y-Chromosome ancestry along with a genetic marker that defined a unique *haplogroup*, in this case Haplogroup M (Wells 2006, 180-182). This marker maps out *Homo sapiens* beachcombing and coastal settlement beyond Africa—across southern Arabia, Oman, and the United Arab Emirates, South Asia into Pakistan, and northern India (Wells 2006, 180-182). The evidence indicates that the environment on the southern Arabian coast was more congenial than now, making possible progress that took modern humans to South Asia, Australia, and the coast of China.

While this Red Sea crossing could be reached from the inland Rift Valley of Africa—and may well have included a contingent of Rift Valley migrants—it is also the logical termination of an East African coastal route. Vincent Macaulay *et al* (2005) has characterized the crossing to Arabia as a "single, rapid coastal settlement of Asia," which we might guess corresponded to a favorable water level, a congenial climate event, or even a particularly enthusiastic group of adventurous leaders. However it was motivated, those who made the crossing appear to have been a coherent group of similar genetic makeup that carried only a portion of the genetic richness of the African population left behind. The constraints of this portion provide a way to guess how many migrants made the crossing: As reported by Nicholas Wade (1997), University of Maryland anthropologist Sarah Tishkoff estimates a group if 200 to 500 migrants, but Wade subsequently suggested as few as 150 (2006, 81).

Until recently, this crossing has been placed between 70,000 and 60,000 BP, but Armitage *et al.*

(2011) suggest that migration across Southern Arabia may have occurred during the final millennia of Marine Isotope Stage 6 (MIS 6), 130,000 to 125,000 BP. During this glacial maximum, sea level was lowest and the width of the strait at *Bab-el Mandab* was at its narrowest, allowing for movement of a substantial population evidently never in danger of extinction. This earlier date is supported by stone tools from river beds in the Dhofar Mountains of southern Oman (Groucutt 2018) dating to more than 100,000 BP (Underwood 2011), illustrating a microlithic blade toolkit previously known only in Sudan. J. I. Rose (2007) has colorfully referred to this as "a trail of stone bread crumbs" from Sudan to Arabia. Precise dating for the earliest or latest departure from Africa has yet to be determined, but archeological and genetic evidence indicates this migration across Arabia and on to South Asian coasts was primary, as opposed to a northern departure through Sinai.

Wade (2006, 75) provides a map clearly marking the coastal route from Africa to Australia, but this route, now known as the Southern Dispersal Route, turns northward in the Indonesian islands and continues up the coast of East Asia to Siberia (Figure 4), and on to the Americas.

Higher sea level today along the coasts of Yemen, Oman, and the United Arab Emirates obscures coastal conditions at the end of Marine Isotope Stage 6 and early MIS 5; as Faure *et al.* (2002) point out, when sea level is lower, freshwater springs appear on emergent continental shelves—a result of a steepened downhill gradient from inland aquifers—providing a ready source of water for coastal migrants. An interesting segment on the video series, *The Incredible Human Journey* (Roberts 2009), has Alice Roberts with J. I. Rose boating off the southern coast of Arabia with Rose explaining the availability of fresh water from springs now submerged by sea-level rise. Regions of coastal vegetation associated with such springs along the southern margin of Arabia made for an easy transit to southeast Arabia where excavations at Jebel Faya in the United Arab Emirates indicate possible occupation by 130,000 BP.

Arrival at the mouths of the Tigris and Euphrates Rivers, which empty into the Persian Gulf, may well have presented a momentous choice, for these were the first major sources of fresh water from the interior

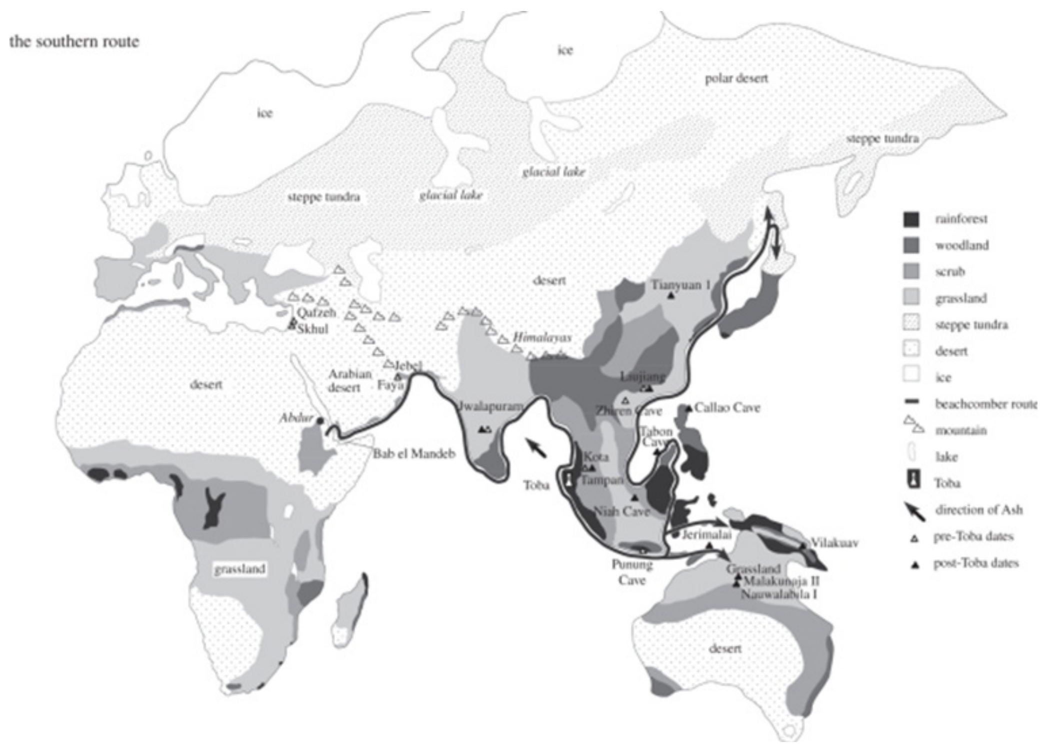

Figure 4. The crossing of the Red Sea from Africa to Arabia at *Bab el Mandab* marks the beginning of what is now called the Southern Dispersal route. The resulting coastal route follows the vast circuit of South Asian beaches on the Indian Ocean through India and Indonesia, then heads north from Indonesia, to the Philippines, China, Taiwan, Korea, Japan, and the Pacific coast to Siberia. Oppenheimer (2012) calls it the "beachcomber route." Image source: www. royalsocietypublishing.org.

encountered by Southern Dispersal migrants. We will return to this later, noting here that this may have been a primary decision point where some migrants chose inland riverine rather than coastal migration, eventually becoming the founding population of the Asian interior and Europe.

The evidence from South Asia indicates that coastal trekking continued, probably along now submerged beaches of what are now Kuwait, Iraq, Iran, and Pakistan to Southern India. The western coast of India is short on material evidence. Here, as with the eastern coast of Africa, sea level 100 to 110 meters (300 to 400 feet) below the present level means prehistoric beaches are now submerged—in some cases along the west coast of India as much as 200 km (120 miles) offshore. The actual beaches followed by migrants harvesting seafood are thus now underwater with evidence of temporary settlements and middens washed away by rising tides. However, riverine migration points to the rich South India archeological site at Jwalapuram, inland on the Krishna River. Here microblade stone tools analogous to African predecessors extend the "trail of stone bread crumbs" that began in the Sudan. Indian sites provide evidence for dating: arrival of *Homo sapiens* at this subcontinent India site occurred after a now-reliably dated geological event. At 74,000 BP, the Mount Toba volcano in northern Sumatra erupted in what is now recognized as the most violent volcanic event of the Pleistocene Era. Remnants are evident all across Southeast Asia and India thousands of miles away. As Petraglia *et al* (2007) have documented, microblade lithic technology is evident at Jwalapuram shortly after the Toba event.

This extended inland settlement at Jwalapuram points to a feature of migration routes deriving from human behavior. People naturally fall into separate groups: contented settlers and adventurous explorers. Many years ago, anthropologists R. B. Lee and I. DeVore (1968, 245-249) worked out a mean size for a hunting-and-foraging band as around thirty individuals, which they called a "magic number" for population maintenance and cooperative sharing. In a resource-rich coastal environment, a group of thirty or more could subsist indefinitely at a convenient location near fresh water. But the rich marine resources and nutritional benefits of a coastal environment would soon lead to population increase, pushing population within a few years to forty, or perhaps fifty within a generation. Such increase would thus provide a motivation for group separation. Contented settlers might remain behind while adventurous explorers would push on, and some might choose a riverine route inland. Thus, as Wade writes, "in a century—five generations—a hunter-gatherer society might spread over a considerable distance . . . [T]hose long distance migrations . . . were not made by a single group on a long trek, but were the slow expansion of human populations who took a generation to travel each leg of the journey. . . . The world would thus fill up in a rather orderly way" (2006, 77-78). Over many generations, the settlers would develop localized genetic markers while adventurers would develop new markers that can be traced through later settlements along extended migration routes. Genetic mutations thus provide a permanent "memory" of human movement that can be discovered by DNA analysis of long-established indigenous people.

Coastal Migration Beyond India

Somewhere east of India, a single coastal route appears to have bifurcated into two. One led southward across the exposed bed of the Bay of Bengal to the Andaman Islands, then island hopped to the Nicobar Islands, Sumatra, and Island Southeast Asia. The efficacy of this route has come clear from genetic analysis of Andaman Islanders, a relict population that has occupied the archipelago for millennia (Thangaraj *et al.* 2003, 2005). The other followed the coast of Bangladesh, Myanmar, Thailand, and the Malay Peninsula to Island Indonesia where conceivably separate populations eventually melded. The whole complex story of migration in Island Southeast Asia is told in a revised presentation by Peter Bellwood (2017).

Coastal migration in Southeast Asia was much more complex and ultimately more challenging than coastal trekking in Africa or South Asia, which feature fewer offshore islands. Initially, Southeast Asia was more peninsular than insular: lowered sea level turned sea bottom between Borneo, Java, Malaysia, and Sumatra into a linking lowland (called Sunda), a mixture of wetland and mangrove forest that no longer exists; numerous lands once joined are now separated. At the same time, much of present day Indonesia east of Borneo remained insular, which presented a water-crossing challenge for further movement. An oceanic barrier separated Borneo from Sulawesi and New Guinea, preventing animal migration—evident in the biological dividing line noted by Alfred Russell Wallace (the Wallace Line). This ocean divide isolated New Guinea and regions south and thus confined Australian fauna to a distinctive evolutionary path. But what separated animals did not prevent more enterprising humans from eventually making the crossing.

For two decades skeletons from the Lake Mungo site in New South Wales have provided 42.000 BP as benchmark date for the arrival of modern humans in Australia (Thorne 1999). At Madjedbebe, however, a rock shelter in Northern Australia, a series of progressively more refined excavations (1973, 1989, 2012, 2015) have turned up silcrete flakes, ground ochre, a grind-stone, and more than 12,000 stone artefacts. Advanced dating methods have yielded a much earlier age of 65,000 BP (Clarkson 2017)—a date which defines a minimum for departure from Africa and a narrow arrival window between 65,000 and 74,000 for arrival in India and regions in the vicinity of the Toba eruption.

Today, Southeast Asia is a land of islands: the Andaman-Nicobar archipelagos have 572, Malaysia has 878, Indonesia 18,307, Philippines 7,641, and despite the impression that Australia consists of one large island, there are 8,222 within its maritime borders. This astonishing total of more than 35,000 islands constitutes a ratio difference of coast to land such that beachcombing dominated food gathering, and more recent migration has almost always been coastal.

We recall that migrants from Africa crossed to Arabia bearing the M genetic marker. One variant, M 168, arose in northeast Africa, traveled across the Gate of Grief to Arabia, and eventually became the ancestor of inland migrants to the north in Eurasia (Wells 2002, 73). Then, somewhere along the coastal route of South Asia, probably after 75,000 B.P., an individual was born with another variant, giving rise to M 130. The travels of M and M 130 form the plot of a coastal narrative tracing arrivals of the earliest population: M 130 increases from 5% among the Adi and Negritos of India and the Andaman Islands, 10% of the *Orang asli* (Original people) in Malaysia, 15 % or original tribes in New Guinea, and 60% among the Australian Aborigines. M 1 is found in 20 percent of mitochondrial types in India and nearly 100 percent in Australia (Wells 3002, 72-74). Following the challenges of water crossing from Borneo to New Guinea, migration southward to Australia presented few challenges. Lowered sea level had exposed a considerable expanse of seafloor—another prehistoric geographical area now known as Sahul. Seacoast migration down its western beaches would have led to north central Australia to the region of the Madjedbebe rock shelter near the coast (Clarkson 2017) already mentioned.

Dates now well attested provide a chronology for the Southern Dispersal narrative or Oppenheimer's Beachcomber Route: a departure from Africa between 120,000 and 80,000 BP, presence in India around 74,000 BP, arrival in Australia by 65,000 BP. With the subsequent arrival of the aboriginal Palawa in Tasmania approximately 40,000 BP, a coastal trek of thirty to eighty thousand years had reached a migratory end of the world. Meanwhile, a longer coastline remained to be discovered—a route north that would lead human adventurers on a still longer migration, ultimately to the most remote lands end in the greatest journey every made.

Trekking East Asian Beaches

Migration north along the coast of China is almost a certainty given the distribution of genetic markers along the East Asian coast. Capelli *et al* (2001) have shown that Y-chromosome DNA Haplogroup O3-M122 ("M" showing continuity with the coastal route out of Africa) is found among Chinese, Filipinos, Vietnamese, Taiwanese, and Koreans; additionally, Haplogroup 01a-M119 provides a further link between Filipinos and Taiwanese. Chang *et al* (2002) have shown that other genetic markers are common among Thais, Chinese, Indonesians, and Filipinos. It seems clear that some migrants from the Southern Dispersal route moved inland from Thailand across Laos, to Vietnam and Southern China where various inland settlement sites attest to *Homo sapiens'* presence (Olsen *et al*. 1992). But the southern branch of migrants who moved through the Malay Peninsula across Sunda to Borneo eventually brought Island Southeast Asia markers by a roundabout route to coastal East Asia. Tracking the migration route of coastal markers and haplogroups is difficult, however, because a shallow continental shelf off the coast of China means that temporary settlements, prehistoric worksites, and marine resource middens are now many miles offshore, inundated and destroyed by rising waters.

Offshore islands and archipelagos, however, are proxies for coastal continuity. The island of Palawan which runs diagonally for 280 miles between Borneo to the southwest and Mindanao on the northeast is a case in point. During the movement of *Homo sapiens* into Island Southeast Asia when sea level was lower, Palawan was connected to Borneo, providing a migration route that is verified by the 1962 discovery of human remains and extensive toolmaking worksites of the Tabon Cave complex dating to 47,000 BP. For more than half a century, Palawan has been celebrated as the Cradle of Philippine Civilization. Despite intervening ocean between Palawan and Mindanao, Palawan is the logical launching point for migration into the Philippines which was at that time a single landmass stretching north-south for 1500 kilometers (1100 miles). Subsequent sea level rise has now resolved this into an archipelago of 7,641 islands. More recently, Henderson *et al* (2007) have reported the 2007 discovery of a *Homo sapiens* foot bone at Callao Caves at the northern extremity of the Philippines that has superseded the Tabon Cave discoveries, pushing *Homo sapiens* occupation back to 67,700 BP.

The most dramatic effect of sea level as much as 120 meters (400 feet) lower than today was exposure of the entire seabed of the Taiwan Strait. At a distance of 130 kilometers (100+ miles), present-day Taiwan is out of sight from mainland China, but during glacial times the exposed seabed formed a convenient land bridge across which faunal species and coastal *Homo sapiens* could traverse. In 1972, human fossils were discovered in the Zuozhen District on the northeast coast of Taiwan, including cranial fragments and a molar. Scientific advances have allowed for a dating of "Zuozhen Man" between 20,000 and 30,000 years BP (Liu 2009). Access to Japan from the mainland was also relatively easy from Korea at the southern end or Siberia to the north, particularly when lowered sea level reduced distances from the mainland. Fossils from three caves in Japan—Yamashita, Sakitari, and Shiraho-Saonetabaru—have yielded to Carbon 14 analysis with concordant dates of 32,000 to 27,000 BP (Matsu'ura 1999, Nakagawa 2010, Shinoda 2017), while an extensive dated killsite of prehistoric elephants--part of worldwide megafauna hunting that appears to have led to extinction—provides evidence of human presence as early as 40,000 BP.

From Siberia to the Americas

Today we know that modern humans had reached southern Siberia by 40,000 BP. One obvious route would follow from South Asian coastal separation, with riverine migrants from the Tigress-Euphrates Rivers pushing northward through the Black Sea-Caspian gap to Central Asia. All such summaries of migration routes must be qualified by remembering that movement may have averaged no more than a few feet per year and would have required numerous adaptations to new environments, climate variations, and a gradual shift away from floral toward faunal food sources. But evidence along the way testifies to their acquisition of effective survival skills, including the remarkable mammoth bone shelters found in Ukraine in the valleys of the Don and DNiepr Rivers (Iakovleva and Djindjian 2005). Their expansion to the frigid expanse a few hundred miles from Ice Age glaciers may have taken as much as 20,000 to 30,000 years and thousands of generations.

Additional technological invention made survival in the coldest regions of the planet possible. Foremost is a hunting toolkit—spears and butchering blades; however caches of bone needles dating to 35,000 BP found across northern Eurasia testify to the mastery of sewing and the fashioning of skin-tight clothing needed for survival in Arctic climates, making the needle one of humanity's transformative inventions.

Additional technological invention occurred around the time of the last glacial maximum, 25,000 BP, with the appearance of a microblade technology in the Altai and Lake Baikal regions (Goebel 2002; Kuzman *et al*, 2007)—first bifaces then microblades useful for survival in Arctic regions where big game hunting was the primary source of food. A similar sequence of microblade technology is evident a few millennia later in Japan and the Ushki Lake site in the Kamchatka Peninsula (Goebel *et al*, 2010). Along the edge of glaciers in Siberia, there appears to have been east-west movement, possibility because such populations were dependent on migrating herds of caribou and other large game. Theodore Shurr (2015) cites genetic evidence for population expansion from the Altai-Sayan region eastward toward Beringia around 25,000 BP carrying genetic markers that show up in later Amerindian populations. These migrants from west-central Siberia contributed a distinctive Y Chromosome marker, M242, that had separated at least 20,000 years earlier somewhere along the South Asian coastal route. Other microblade-equipped migrants moving north of Japan through the region of the Kamchatka Peninsula carried M13O, the defining genetic marker brought from the Horn of Africa, across the Gate of Grief, along the coast of South Asia, and up the coast of East Asia. Coming together in the Kamchatka region of northwest Siberia, these markers became the distinctive genetic components of migrants to the Americas.

Popular interest in the origin of First Nations Canadians, Native Americans, and archaic precursors of Central American civilizations dates to Thomas Canby's *National Geographic* article, "The Search for the First Americans" (September 1979) which followed his year spent with archeologists searching and excavating North and South American sites. Articulate in its treatment of migration, cautious with dates, informative on the development of agriculture in Mexico, and well-illustrated, the article provided an overview of then current knowledge still readable today.

Figure 5. Bone needles made from the dense foreleg bones of horses or other hooved mammals display acquired skills of carving, smoothing and drilling. Caches of bone needles carbon dated to c. 35,000 BP have been found at several north European and Asian locations. Traveling, hunting, and dwelling in Arctic regions depended on the ability to fashion skin-tight clothing—shirts, pants, parkas, boots, and gloves. Image Source: Gilda Lyons. www.gildalyons.com.

The Kamchatka Peninsula marked the beginning of an expansive region that extended from northeast Siberia to Alaska, including exposed seafloor extending north into the Arctic Ocean and south into the Pacific to the Aleutian Islands. It existed because so much water (70 million cubic miles) was tied up in continental ice during the Last Glacial Maximum that sea level was 100 to 120 meters (320 to 400 feet) lower than today. Typically referred to as a "land bridge" between Alaska and North America, this region is now called Beringia (Fig. 8), the name given to it by the Swedish geographer Eric Hulten (1937). This ecologically unified region stretched 1,000 miles east to west and 600 miles from north to south—all in all 620,000 square miles, greater than the combined area of Texas, New Mexico, Arizona, and Nevada. This vast region was the vestibule across which Asian travelers reached the Americas.

Given how recently we understood the movements of people in prehistoric times, it comes as a surprise that the first speculation about human migration from Asia was published in 1797 by Thomas Jefferson (1954, 100-101): "[G]reat question has arisen from

Figure 6. Beringia is the geographical name for the "land bridge" between Siberia and Alaska. With sea level 100 to 120 meters lower than today, extensive regions of continental shelf were above sea level, rich in flora and fauna, and thus a suitable habitat for prehistoric *Homo sapiens* who settled here for 10,000 to 15,000 years, a period known as the Beringia Standstill. Image source: www.pinterest.com.

whence came those aboriginal inhabitants of America? . . . [T]he late discoveries of Captain Cook, coasting from Kamchatka to California, have proved that, if the two continents of Asia and America be separated at all, it is only by a narrow straight. So that from this side also, inhabitants may have passed into America." Jefferson made this guess because of "the resemblance between the Indians of America and the inhabitants of Asia." The evidence today is a version of Jefferson's casual observation: the resemblance of genes between the Indians of America and the inhabitants of Asia. The story is more complex, of course, but Jefferson should not be dismissed as simply hazarding a lucky guess.

The evidence—not only a toolkit that included sewing needles and microblade technology but also traceable genetic markers—suggests that by 30,000 BP some groups had reached Beringia. Evidence for *Homo sapiens* presence in North and South America provides a considerably later date, around 14,000 BP. This time lag of an estimated 16,000 years remained an anthropological mystery for several decades until it was realized that Beringia was a habitable ecosystem during this period when glaciation blocked movement beyond Alaska. Faunal resources included bison, caribou, horses, lions, mammoths, musk-oxen, saga antelopes, and woolly rhinoceros, along with a variety of sea mammals (Brigham-Grette *et al*. 2004). For this entire period, all of Beringia except the southeast coast was free of glacial ice. It was rich in floral and faunal resources, with ocean shores the usual reliable source of food resources. The idea that Beringia had served as a habitable refuge for humans for an extended period was first suggested by Hulten (1937)), a botanist as well as geographer, who explored the region and published extensively on the rich flora of the region from the Yukon to Siberia, but his suggestion remained for decades little more than interesting speculation.

Most early discussions of human migration were speculative guesswork and remained so until hard scientific evidence emerged. The Eskimo-Aleut family of languages which ranges from Alaska across northern Canada is related to the easternmost branches of the Eurasiatic family (Ruhlen 1994, 169-170) most notably Siberian-Yupik spoken by the Yupik people of the Chukotka Peninsula of northeast Russia, though linguistic similarities between North American and Asia languages provide soft evidence. The resemblances between northern Asian mythology and legends of Inuits, Eskimos, and First Nations tribes of Canada suggests continuities between Asia and North America that indicate what has been called a circumpolar culture, but these resemblances do not achieve the rigor of scientific evidence. Today, genetics has become the definitive arbiter.

At the inception of genetic studies, Torroni *et al* (1993) isolated four founding mtDNA haplogroups unique to archaic inhabitants of the Americas, identifying them as A, B, C, and D, which have become the first four letters of the phylogenetic alphabet. The theory of a "Beringian Standstill," put forward by Tamm *et al* (2007), based on Hulten's inventory of a supportive floral ecosystem, is also known as the Beringian Incubation Model, a term that captures what happened genetically. Over a period of approximately 16,000 years, four unique mutations were incubated through some 700 to 900 generations of Beringians. Eventually, A, B, C, and D were carried south as the four definitive mtDNA haplogroup markers of the founding population of the Americas.

Peopling the Americas

While Canada remained locked in glaciers, migration of archaic humans from Beringia was impossible: a 2000-mile trek of prehistoric *Homo sapiens* across glaciers rising hundreds of feet above the land without ready access to a food source was beyond possibility. Migration south had to await the waning of these glaciers. In the 1950s, glaciologists theorized that ice melt would have led to a separation of the eastern Laurentide glacier and the Cordilleran coastal glacier, resulting in a theoretical "ice-free corridor" along the eastern edge of the Rockies in the present Canadian province of Alberta. Leading into Montana, the corridor migration idea gained immediate popularity for several decades, partially because it led into the continental interior and thus suited the prevailing theory that the first Native American culture was the Clovis, named for a distinctive tool culture first unearthed deep in the American interior at Clovis, New Mexico.

The hold that the ice-free corridor maintained over the imagination is well illustrated in Dan Cushman's book *The Great North Trail* (1966). This is a great period piece written with a flair for telling detail that links up the Alaska-to-Montana route, "The Trail of All Ages," to numerous other northern trails—for instance the cattle trails—running north from Texas. His linking of various historical trails to the original migration route into the Americas reveals that he preferred a very broad and imaginative view of history; he could be considered an early big historian. This is particularly evident in his chapter, "The Trail of the Three-toed Horse," located at the center of the book, which explores the prehistory of the horse and in fact a variety of ancient megafauna. But his treatment of the Alaska-to-Montana route was too early for factually accurate information or a plausible account of archaic people's entry into North America.

Putting aside Cushman's "trail of all ages," his romanticized subtitle, through glaciated regions of Canada, this route was not available until some time after glacial melt set in around 16,000 BP; a navigable corridor would not have opened up until around 13,000 BP. While geologists have verified the possibility of this later ice-free corridor, its practicality was questioned by anthropologist Knut Fladmark (1979); any such corridor would run between 1,000-meter-high ice cliffs. Thomas Canby (1979) suggested that it would be a "formidable place . . . an ice-walled valley of frigid winds, fierce snows, and clinging fogs." Brian Fagan (1987, 140) added that it was "at best, one of the most barren and impoverished landscapes that human beings could possibly exploit."

While Dan Cushman had imaginatively thought this route was possible, it was in fact bounded by hazardous ice cliffs, threatened by sudden ice falls, awash for centuries with freezing melt water, glacial lakes, and a constantly changing environment that would have delayed the development of a supportive ecosystem. A study of ancient DNA along the corridor route led by Eske Willerslev has worked out an evolutionary narrative of the corridor showing that a lack of floral resources, wood for fuel and tools, and game animals made the corridor "biologically unviable" before 12,600 BP (Wilken 2016). Additionally, no trace of human movement over the 1500 kilometer (1000 mile) route between Alaska and Montana has been discovered.

More than half a century ago, Wilson Duff' (1964, 7) hazarded a guess that "the Indian history of British Columbia . . . began at least a hundred centuries before the Province itself was born." His estimate has turned out to be a considerable underestimate. Critical of the ice-free corridor theory, Fladmark (1979) argued for a Pacific Coastal Route, which is now recognized as more probable for several reasons. The earliest effect of glacial melt was a drawback of the Cordilleran Glacier from the coast which exposed the beaches of southern Alaska and the continental margin of British Columbia. The establishment of a coastal floral ecosystem and faunal entry would follow within centuries, perhaps decades. According to Carol Mandryck *et al* (2001) "paleoecological data suggest that the coastal landscape was in part vegetated and probably able to support a terrestrial fauna, including humans." Lesnek *at al* (2018), have suggested a precise chronology: "Recent paleogenetic analyses suggest that the initial colonization from Beringia took place as early as 16 thousand years (ka) ago via a deglaciated corridor along the North Pacific coast. . . . productive marine and terrestrial ecosystems were established almost immediately . . . an open and ecologically viable pathway through southeastern Alaska was available after 17,000 years ago."

While the ancient Pacific shoreline is now as much as 100 meters below present sea level, the exposed continental shelf extended far to the west of today's hazardous shoreline reefs and rocks. Early speculation that watercraft would be needed was imaginatively predicated on skirting the hazardous coast of cliffs, offshore rocks, and crashing surf of the continental margin all the way south to Oregon and Northern California, but this has been dismissed as probably beyond the construction skills of archaic Beringians—at least at this early date. The evidence suggests that a walkable coastal route was viable almost as soon as ice melt began, perhaps earlier. The outermost shore, often corresponding to the western margins of today's offshore islands—Prince Edward Island, Haida Gwaii, and Vancouver Island—were ice free and thus a suitable habitat for floral and faunal resources. Heaton (1996), for instance, has shown that Prince Edward Island on the southeast coast of Alaska was a refuge for the brown bear over a period of 40,000 years, an index of its suitability for a wide range of mammalian species, including human migrants.

One decisive piece of evidence is the presence of archaic Indians in a few sites in the Americas long before the ice free corridor was ecologically viable. An analysis of trace fossil coprolites from Paisley Caves led by Eske Willerslev (Gilbert 2008) indicates a human presence in Oregon by 14,000 BP, fourteen centuries before the ice free corridor could support human presence. Even more surprising is evidence from the Monte Verde site in Chile which shows that modern humans had reached it by 14,000 BP, a dating indicating an astonishingly rapid dispersal of early humans throughout the Americas. Additionally, it is almost impossible to imagine archaic humans traveling the interior for the whole length of the Americas so rapidly; too many habitable environments along the way would have waylaid dispersal. In contrast, littoral migration is likely to lead migrants forward. A mere ten miles per year—little more than a week of leisurely ambling—would have taken early migrants the length of the Americas in a single millennium.

Trekking the Coast

Keeping in mind the usual behavioral division between settlers and adventurers, we would expect a trail of relict settlements marking the passage south, left behind by adventurers who did not hesitate to move on. The later descendants of these settlers left a genetic trail that can be found in fossil remains. A surprising spectrum of evidence emerges from virtually every discovery. Excavations at *On Your Knees Cave* on Prince of Wales Island in southeastern Alaska have yielded a microblade and bifacial toolkit along with a 12,000+ BP skeleton remains—called "Shuka Kaa" ("Man Ahead of Us") by the Tlingit tribe of the region. A genetic marker (specifically mtDNA subhaplogroup D4h3) shows he is related to British Columbia tribes to the south—not only Tlingit, but also Haida, Nisga's, and Tsimshian, and in fact to Central and South American groups thousands of miles to the south, the Karitiana and Suruí, and the Ticuna of Brazil's Amazon (Kemp *et al* 2007; Bellwood 2013, 89). Here a single skeleton, combined with genetic collection along thousands of miles of coast, establish an ancient migration trail. This in fact is what we find all down the Pacific coast.

Farther south, the Haida Gwaii archipelago (formerly the Queen Charlotte Islands), located 45 to 60 kilometers (30 to 40 miles) off the mainland coast, was joined to it during the Glacial Maximum; today it is the stronghold of the Haida nation. Various caves—K1, Gaadu Din 1 and 2—have yielded stone tools from approximately 10,000 BP, evidence of Haida ancestors who are thought to have occupied Haida Gwaii since at least 13,000 BP with mitochondrial DNA and Y Chromosome evidence of descent from the ancient inhabitants of Beringia. Given the possible departure from Beringia as early as 16,000 BP, it is possible that additional evidence is awaiting discovery.

Access to seafood is a constant along the Pacific coast. Access to fresh water is equally reliable. Every few miles another stream pours off the coastal mountains, some still fed by glaciers, many more from Pacific moisture and rainfall as offshore winds rise over the coastal range. Numerous fiords provided access to both freshwater and salt water food. The present day Tsimshiam, Gitxsan, Haisla, and Wuikinuxv tribes of British Columbia occupy long-established inland riverine locations settled by coastal migrants. In Washington State, the Makah, Quileute, Hoh, and Coastal Salish are permanent settlers where streams and rivers flow out of the rainforest of the Olympic Mountains. The attractiveness of inland riverine sites is evident with the Walapa tribe who settled inland along the Chehalis and Walapa Rivers. The Chinook tribe settled the mouth of the Columbia River and upriver more than 100 miles to Celilo Falls.

Careful consideration of the Pacific coast as the primary route for the peopling of the Americas lies in the inaccessibility of locations like Haida Gwaii and mainland fiords from any direction other than the north. The entire length and width of British Columbia is riddled with mountains from the coastal range east to the Rockies. These are geological young mountains—jagged and forbidding—assembled from collisions and subduction of the Pacific plate during the complex assembly of western North America. Barely accessible today from the interior except by highways to Prince Rupert and Vancouver, the entire coast was isolated from migrations from the interior, certainly from migratory groups, if any, that might have traveled all the way to Montana before exiting the Ice Free Corridor. The three groups that dominate Vancouver Island, the largest island off the west coast of the Americas, have genetic connections with coastal populations to the north and south; interior genetic markers are derivative. Rich in floral, faunal, and marine resources with warm offshore currents, Vancouver Island is home to three groups, all of which have become well known. The Kwakiutl gained prominence from the novel by Margaret Craven, *I Heard the Owl Call My Name* (1967), which made the New York Times Bestseller List once it was picked up by an American publisher. The Nuu Chah Nulth are known from the adventures of John R. Jewett (1783-1821) who survived a 28-month captivity with this group and wrote a memoir of great anthropological interest—*Narrative of the Suffering of John R. Jewett* (1815). The Coastal Salish occupied coastal regions from Vancouver Island with a prominent presence in the American Northwest. Habitation locations from southeast Alaska to Washington State are most clearly understood as relict sites marking the trail of Beringian migrations southward along the coast.

Recently Duncan McLaren *et al* (2018) discovered 29 archaic human footprints of various sizes on the shore of Calvert Island, British Columbia, dating to 13,000 BP. On Santa Rosa Island, twenty miles off the coast of Santa Barbara, some twenty sites of human occupation have been identified, dating between 12,000 and 11,000 BP. Evidence includes tool-making sites, stone points, and substantial middens of abalone shells (Rick *et al.* 2013). Genetic and archeological evidence have coalesced to establish the Western Coast Route as the primary migration route into the Americas.

Figure 7. The West Coast Route into the Americas has emerged as the most viable way past glaciers during the last Ice Age when shorelines were seaward of present locations. Paleoindian sites on the coast and in the interior indicate rapid dispersal across the continent. Note that the ice-free corridor, once illustrated on virtually every migration map, has here been eclipsed by definitive evidence for the coastal route. Image source: www.TranspacificProject.com

As suggested earlier, successful reconstruction of early migration routes is possible because of constants in human behavior. Some migrants are prepared to settle in a new location if environmental conditions of climate, food, and water are favorable. It is possible that this describes the majority, and most likely elder members of migrating groups. Stability and regional reliability of food resources may encourage expansion up and down the coast and perhaps inland along a waterway where harvesting of riverine resources adds to their diet. The result may be an expansive relict community. Centuries or millennia later, these relict communities preserve genetic markers, making such communities milestones along the original migration route. Meanwhile, adventurers and explorers become restless, choose independence, and move on. Predictably, these will be younger members of the group. They carry the genetic markers of their forebears, but in time new markers emerge that extend the overall direction of migration.

Among the migrants along the primary coastal route into the Americas one would expect more settlers than adventurers and thus a considerable density of settlement population, and, in fact, this is the case. Coastal First Nations tribes of British Columbia and Native American tribes of Washington and Oregon number more than fifty; another fifty occupied California with subgroups adding another forty. Numerous dispersal routes into the interior were available: the Fraser River of British Columbia, the Skagit and Columbia Rivers of Washington, the Umpqua and Rogue Rivers of Oregon, the Klamath and Salinas Rivers of California, and the Colorado River from Mexico. While all presented congenial sites for settlement, those who followed these inland routes were in the minority. Even today, the west coast of both Canada and the United States have the greatest density of indigenous population, with one-third of Native Americans living in California. This reflects their west-coastal entrance into the Americas as surely as the arrival of Europeans on the Atlantic coast is reflected in their greater density along the east coast.

The Central and South American Coastal Route

The huge land masses of North and South America have led to Mexico and particularly Central America regarded primarily as a land bridge, particularly where it narrows to 50 kilometers (30 miles) at the Isthmus of Panama. Certainly, an inventory of prehistoric sites in South America indicates that numerous groups trekked through and well beyond Central America. Though most evidence of coastal settlement may await discovery—or may remain far below today's higher sea level—Central America offered congenial inland environments for settlements that eventually developed into advanced civilizations supported by water-managed cultivation of maize, beans, squash, tomatoes, chilies, and amaranth. The Toltecs developed agriculture enhanced with dams and water channels along Gulf Coast river valleys. The later Aztecs, who gained control from the Gulf of Mexico to the Pacific, developed agriculture using a chinampas system of raised growing beds and water channels. The Mayans developed a similar raised-bed agriculture along with terrace farming in the Yucatan Peninsula. Toltec civilization was based on centuries, perhaps millennia, of in situ settlement such that they developed an advanced sculpture tradition; both the Aztecs and the Mayans constructed monumental civilizations of quarried stone with considerable social complexity and associated political organization reminiscent of Old World cultures of the Nile, Tigris-Euphrates, and Indus River Valleys.

While these Central American civilizations developed on an agricultural foundation, many early migrants moved beyond to the southern continent. In a survey of the late Pleistocene in South America, Tom Dillehay (1999, Fig. 1) mapped 41 sites, more than 20 of them west of the Andes along the Pacific coastal route from Columbia to Patagonia.

Coastal Peru may eventually yield evidence of archaic migrant passage and settlement, though scores of well-developed sites in the Peruvian Andes testify to congenial climate and supportive resources that resulted in stable settlements lasting centuries or millennia. On the coast of Ecuador, a cluster of sites has revealed reliance on marine food resources, including tidal zone and estuary mangrove waters. Some 32 archaic sites have been identified on the Santa Elena Peninsula, known collectively as the Las Vegas site. Site 80, 3 kilometers (2 miles) from the coast, is characterized by a 4,000-year-old midden, the lowest level of which has been carbon dated to 10,400 BP (Stothert 1988). However, nearby beachside camps and shell middens indicate short-term or occasional occupation and reliance on faunal and floral foods, but also marine resources, inventoried as 25 varieties of fish, 1 crustacean, and 15 mollusks. Stothert (2011, 373) estimates the occupants of Las Vegas site 90 relied on marine and estuary resources for half their food. The species consumed were almost all shallow water species, suggesting almost daily fishing while wading rather than reliance on any kind of water craft. The dominance of mangrove clam shells (57-80%) may indicate the convenience of harvesting nearby mangrove waters. Lacking evidence otherwise, shallow water harvesting likely characterized marine harvesting throughout the entire coastal migration out of Africa. Long occupation provides evidence that applies to every relict coastal settlement: marine resource reliability accounts for the primacy of beachcombing and coastal settlement that characterized prehistoric life.

In 1975, anthropologist Tom Dillehay discovered an open-air site in Chile on a river tributary at Monte Verde, 58 kilometers (38 miles) from the Pacific coast. The importance for the chronology of migration in the New World and the wealth of artifacts recovered at this site have been discussed in detail (Fagan 1987, 174-175; Dillehay 1999, 2000; Bellwood 2013). Preserved by a peat-filled bog, the site yielded bones, charcoal, pieces of hide clothing, remains of posts from a dozen huts, and a piece of meat from which DNA could be extracted. The site, dated to 14,800 BP appears to have been occupied by a typical foraging group of around 30 individuals with evidence of a mixed floral, faunal, and marine diet. As noted earlier, the dating of Monte Verde, which predates a viable ice-free corridor through Canada by many centuries, provides primary confirmation of a coastal rather than inland migration, though the early arrival at Monte Verde provides an astonishing scenario of 10,000 miles of rapid peopling of South America. In this connection, Peter Bellwood (2013, 91) suggests that a migrant population could have "made its way down the long western edge of the Americas in just two short millennia between 16,000 and 14,000 years ago. . . . A few hundred pioneers doubling their population every 50 or 100 years or so would have had little difficulty in traversing such a distance very quickly, and keeping contact with other groups left behind." Monte Verde is in fact the oldest confirmed site in the Americas. A relative lack of stone tools indicates that this group did not rely on hunting but were primarily foragers, depending on floral gathering and harvesting of marine resources—undoubtedly a legacy of millennia of trekking ocean coasts.

Figure 8. A proliferation of late Pleistocene sites west of the Andes marks the primary coastal migration route. The following sites are referred to in the text: 6. Las Vegas; 30. Mylodon Cave, Cueva del Medio; 36. Monte Verde. Map source: Dillehay 1999.

The final leg of this human odyssey occurred when humans reached Patagonia, the southern extremity of South America. The Milodon Cave ("Cueva del Milodon"), now a National Monument, is named for remnants of the prehistoric Milodon that went extinct in excess of 10,000 BP. Fire-fractured stone and lithic tools have been recovered from the cave along with human remnants. Off the west coast route but located on the Pinturas River of Argentina, the Cave of the Hands ("Cueva de Las Manos") shows evidence of occupation as early as 13,000 BP. Its art work from which it takes its name features numerous stenciled hands, carbon dated from the bone-made pipes used to spray paint at 9300 BP. Similar images of hands, nearly always the left hand, are well known from Neolithic cave art in France.

The 2500-mile coast of Chile, which includes Patagonia, and the Tiera de Fuego archipelago,

Figure 9. Patagonia, the final stop on the great migration, is a hostile environment of numerous islands, ragged mountains, inland waterways, and rich marine resources that have served *Homo sapiens* migrants for thousands of years.

Image source: www.patagonia.com.

is one of the most hostile coasts of the world. Islands number 4,872 with few inhabited and most inhospitable.

The region is rich in seafood along hundreds of miles of inland waterways. Spa Piana and Orquera (2009) have pointed out that the settlers of Patagonia and Tierra del Fuego "became intensely dependent on the littoral and marine resources and designed special technological means for their procurement and processing, including navigation." Given the extent of islands and waterways at the extremity of South America and the near-freezing temperatures of ocean waters, it is likely that migrants to Patagonia were impelled to developed watercraft at an early date, perhaps within a century or two following their arrival.

In assessing the early settlement of South America, Tom Dillehay (1999, 206-207) writes, "Being the last continent occupied by humans but one of the earliest where domestication occurred, South America offers an important study of rapid cultural change and regional adaptation." Among a number or richly suggestive "triggering mechanisms," Dillehay points to the coastal environment, particularly the "constantly changing lifestyle of *Homo sapiens* resulting from having traversed the entire span of the Western Hemisphere." His focus on the coastal environment might well apply to the entire ocean-margin migration with its constantly reliable marine resources that led humans from South Africa to Patagonia, a trek that unfolded over more than 60,000 years. *National Geographic* (March 2006) called it "the greatest journey ever told."

Interior Riverine Migration

Bringing together diverse discoveries and focused excavations from around the world allows us to construct a primary route for the peopling of the world. Organized chronologically into a continuous narrative, secondary migrations come into focus. In addition to a constant, reliable food source provided by marine resources, humans need daily access to fresh water. This makes streams and river mouths along ocean coasts the necessary stopping points for coastal migrants. Between South Africa and Patagonia these number in the hundreds. Offering freshwater riverine resources, most streams flowing from interior uplands would invite upstream migration. In some cases, such riverine migrations would open up congenial environments away from ocean storms and winds.

With this in mind, we can point to inland riverine settlement from which we can infer prehistoric foraging migration. The Tigris-Euphrates valley, as noted earlier, provides the first route of dispersal separation from the primary coastal route. Mesopotamia and the surrounding hills are the most excavated in the world; traces of prehistoric settlements and worksites in the surrounding Zagros Mountains number in the hundreds, suggesting long occupation and population growth. Charles Keith Maisels (1990, 124) estimates that the region eventually harbored 2000 to 4000 foraging groups of 50 to 100 members. Later Mesopotamian cities—Ur, Eridu, Nippur, Kish, Babylon, and Mari—may well have occupied early settlement sites no longer accessible. In addition, the Tigris-Euphrates route north provided a migration corridor which, with minor directional changes, points northwest toward Anatolia (Turkey), the doorstep of Europe, and directly north toward the interior of Asia. Somewhere just east of the Horn of Africa, haplogroups N (mtDNA) and R (Y DNA) evolved from the M haplogroup, probably as early as 80,000 BP. Torroni *et al* (2006) argue that M, N, and R occurred between East Africa and the Persian Gulf; the presence of N and R across the entire Eurasian region to the north suggests that riverine routes north on the Tigris and Euphrates may well be a secondary route of great importance in populating the north.

Farther east on the South Asian coastal route, the Indus River invited migrants to the uplands of Pakistan where, much later, dozens of congenial riverine sites were established that eventually evolved into an immense civilization. The sites of the now ruined cities of Harappa and Mohenjo Daro were probably occupied by some of the earliest riverine migrants away from ocean shores. On the west coast of India the Narmada and Tapi Rivers provided routes to the central interior of India, but the majority of peninsular India rivers arose in the west and flowed east to the Bay of Bengal—among them the Krishna and Godivari with their numerous tributaries, and the Brahmani and Mahanadi Rivers. The grandfather of all inland riverine routes followed the Ganges and its numerous tributaries, which form a vast fertile watershed fed by Himalayan glaciers. It is the second largest watershed on the planet, draining 1,086,000 km^2, including parts of Bangladesh, Nepal, and Pakistan. The environmental richness of the Indian subcontinent, including riverine food resources, undoubtedly attracted numerous inland settlements in prehistoric times, and eventually one of the richest cultures on the planet; here, both Hinduism and Buddhism were born.

Farther east, the Irawaddy River of Myanmar provided a similar route into the Himalayan foothills with long-occupied locations evolving into the later sites of Yangon (Rangoon), Paya (Prome), Bagan, and Mandalay. The rich environment and monumental structures of Angkor covering 400 square kilometers on a tributary of the Mekong River suggests it may have developed on archaic sites of riverine migrants in Kambodja (Cambodia) millennia earlier. In China, the Huang Ho (Yellow River) stretching 5464 kilometers (3395 miles) deep into the continent was the site of prehistoric settlement where Chinese civilization first emerged. Heavily populated and ravaged by numerous flood events, it is likely that most archaic sites have been washed away, though any of ten major cities on the Huang Ho may be located where precivilized *Homo sapiens* first settled. To the south, the multi-tributary Yangtse River, the longest river in Asia, flows 6380 kilometers (3964 miles), past dozens of riverine sites, including Nanying and Shanghai, before emptying into the Pacific. While some migrants reached China from the western interior, these East Asian Rivers provided the most accessible, reliable, and probably the earliest routes into the interior from the primary coastal route.

In North America, the Fraser River, stretching 1375 kilometers (854 miles) provided a route into the interior valleys of British Columbia. Following the border of Washington State and Oregon, the Columbia River, with Okanagan, Bitterroot, and Snake River tributaries, provided a 2000 kilometer (1200 mile) riverine route to the Rockies of Canada and the United States. First Nations and Native America sites of the Pacific Northwest interior reflect inland riverine migrations of archaic migrants. Emptying into San Francisco Bay, the Sacramento and San Joachin Rivers, with dozens of tributaries flowing out of the Sierra Mountains, provided riverine migration routes into most of the California interior. The Colorado River and its Green River tributary provided similar access into Arizona and Utah, regions east into New Mexico and Colorado, and north to Wyoming. The efficacy of this route is clear, for instance, in the discovery of the Native American Palisades *kiva* by the Colorado River in the depths of the Grand Canyon (Harvey 2008)—a structure familiar from the elaborate ruins of the Anasazi in Chaco Canyon.

From the primary coastal route, riverine routes provided access to most of South Asia, East Asia, and North and South America. The geographical configuration of Europe, however, provided a different scenario. With the exception of rivers flowing into the Black Sea—the Dneiper and Danube—that could lead migrants into the European hinterlands, riverine migration along waterways flowing westward into the Atlantic Ocean—the Loire, Seine, Rhine. Elbe, and Vistula—led migrants downstream from sources deep in the interior.

The Greatest Adventure

By the time coastal migrants left Africa, they had accumulated as much as 100,000 years of expertise gathering, hunting, and surviving on marine resources on the south and eastern margins of the continent. The rapid dispersal across South Asia to East Asia added collective experience with a variety of riverine and lacustrine environments over perhaps another 50,000 years. In the coastal archipelagos of Southeast and East Asia, *Homo sapiens* were motivated to develop durable watercraft, a trial-and-error process that may have occurred over millennia with exploration confined to island waterways. Whether powered by sail or oar remains a matter of speculation, though the use of both by Phoenicians, Greeks and Romans during approximately the same era suggests similar navigation methods along Asian coasts. Undoubtedly, ways of collecting rainwater combined with well-honed skills of harvesting marine resources allowed for lengthy adventuring along coasts and among hundreds of islands. At some point, such adventuring expanded into Pacific Ocean exploration.

Seventy years ago, Thor Heyerdahl popularized the idea of oceanic drifting with prevailing winds and ocean currents in his *Kon-Tiki* expedition, but his premise of Pacific island populating from South America has not stood up to genetic analysis of the islanders. Nevertheless, drifting with currents and winds undoubtedly played a part in ocean exploration from Southeast and East Asia. K. R. Howe (2003) has made a case for the earliest explorers rowing or powering into the wind with some confidence that they could reliably backtrack by simply drifting or sailing with the wind. By analogy with the perceptual skills of primitive contemporaries today, we can assume navigation by the Sun, Moon, and stars as a virtual certainty. Familiarity with the seasonal changes in constellation movement along with prevailing sea currents eventually led to confidence, laced with daring and unimaginable bravery, on the open sea.

Sometime around 3500 BCE, adventurers set off on sea voyages that eventually led to the settlement of the Bismarck and Solomon Islands east of New Guinea; then, over the next 4,000 years, Melanesia, Micronesia, and Polynesia. Other scenarios have them departing from the Philippines. Undoubtedly, adventuring beyond the sight of land had occurred with regularity before the greatest exploration adventures began. Nevertheless, the enormous distances between the mainland and Pacific Islands defines this adventure as an act of supreme risk, especially considering the size of this largest ocean on Earth. The odds against making landfall meant that some adventurers, perhaps many, must have been lost; on the other hand, survival skills were well advanced: survival on the ocean over several weeks was possible, thus increasing the odds of reaching landfall. Expedition numbers are impossible to know; there may have been dozens of departures generations apart. Returns may have been few; losses are guesswork. What we do know is that within 3,000 years an extensive array of Pacific Islands was well populated, all the way to Easter Island thousands of miles away from the Asian mainland.

Genetic analysis has made it possible to trace these Pacific island migrations. Linguistic similarities provide expected verification. Cultural continuities illustrate the migration sequences of island hopping and settlement. Similar ritual patterns provide a narrative thread. Island living presented problems never encountered on the mainland where population increase or soil depletion could be ameliorated by simply moving on. Such problems within the confined boundaries of islands forced adaptation that was not always successful; the apparent collapse of living conditions on Easter Island and its diminished population provides the most dramatic example, possibly illustrating environmental or social breakdown, or both. But sometime between 1200 and 900 CE adventurous seafarers sailing north from French Polynesia spotted islands on the horizon and perhaps the rising smoke of eruption from the Kilauea volcano on the Big Island of the Hawaiian archipelago. They pressed on, carrying along their powerful deities led by the goddess Pele, who adopted the Hawaiian volcanos as her own as these migrants adopted these islands as their own. As they pulled their outriggers ashore, they brought to completion a 100,000 year epic of the peopling of the Earth. The greatest journey ever made came to an end on the beaches of the most isolated islands on the planet.

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Forrageamento e assentamentos costeiros: A longa migração da África do Sul para a Patagônia — A maior jornada já feita

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Resumo

Embora os estudos sobre a migração humana pré-histórica cheguem às centenas, uma narrativa unificada e cronológica do povoamento do planeta ainda não foi apresentada. A maioria dos estudos foi produzida por especialistas em uma dada região. A necessidade de uma narrativa de migração específica - destacando uma rota de migração primária - é desejável para uma compreensão coerente da história de como o Homo sapiens pré-histórico povoou o planeta. Reunindo a pesquisa existente, seguimos a principal rota de migração da África do Sul para a Patagônia - uma caminhada costeira ao longo da costa da África, pelas margens do Oceano Índico, seguida por uma caminhada circum-oceânica por todo o Pacífico; toda a jornada, com assentamentos estabelecidos ao longo do caminho, ocorrendo ao longo de um período de 60.000 a 115.000 anos. Da África do Sul, agora reconhecida como refúgio dos primeiros H. sapiens, a migração pode ser rastreada através de fósseis humanos, ocupações de cavernas, acampamentos e locais de trabalho, acúmulos de conchas, restos de animais e de ferramentas. A estes, a genética adicionou a identificação de marcadores genéticos para a determinação de uma rota mais precisa. Essa rota de migração costeira incorpora reavaliações arqueológicas recentes que confirmaram (1) a rota de "Dispersão pelo Sul" da África para o litoral do sul da Ásia; (2) um período de 10.000 a 15.000 mil anos de "Parada Beringiana" durante o Último Máximo Glacial; e (3) uma "Rota Costeira" primária na costa oeste das Américas. A partir dessa rota principal de migração costeira, centenas de rios fornecem entradas ricas em recursos para o interior continental, enquanto o oceano apelava aos aventureiros, esclarecendo assim os estágios iniciais do povoamento da Terra.

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> A rota costeira seria uma espécie de via expressa pré-histórica, permitindo um alto grau de mobilidade sem exigir adaptações complexas a novos ambientes que seriam necessários em uma rota interior (...) devido à facilidade de movimento proporcionada pela costa, a estrada arenosa que circunavegava os continentes, permitiria migrações relativamente rápidas. Não há cadeias de montanhas ou grandes desertos para atravessar, não há necessidade de desenvolver novos kits de ferramentas ou roupas de proteção e nenhuma flutuação drástica na oferta de alimentos.
> – Spenser Wells, *The Journey of Man* (2002)

Meu livro didático de história mundial do ensino médio começava com capítulos sobre egípcios e gregos, mas, por isso, me deixava perplexo. O que aconteceu ao longo de dezenas de milhares ou mesmo milhões de anos desde que os ancestrais primitivos dos seres humanos percorreram as selvas africanas? Em 1956, havia poucas pistas sobre o passado pré-histórico dos seres humanos, mas eu tinha ouvido falar sobre um crânio sul-africano - o crânio de Taung, nome que vim a descobrir muito mais tarde - encontrado em 1924 por Raymond Dart, e chamado por ele de *Australopithecus africanus* - definido como "o homem-símio da África do Sul." Esse hiato vazio de tempo na pré-história do homem persistiu por um longo tempo, e minha leitura de obras como *Outline of History* de H.G. Wells (1920), revisto até o final da Segunda Guerra Mundial, não satisfazia a pergunta. A primeira data historicamente precisa que

Wells poderia fornecer era 776 a.C., derivada de um texto grego que listou os vencedores naquele ano dos Jogos Olímpicos. Eventos de épocas anteriores foram narrados na Ilíada, na Odisseia, no Antigo Testamento e na Epopeia de Gilgamesh, embora quase não se sentisse que algum deles pudesse ser considerado como história factual.

Nas décadas seguintes ao ensino médio, procurei por detalhes na história de origem africana. No quarto de século após a descoberta sul-africana de Dart, a questão recebeu pouca atenção por causa de uma resistência geral à ideia de se ter a África como berço do *H. sapiens*. Havia vários rivais que o antecederam. Um crânio encontrado na ilha de Java (1891-1892), conhecido como "homem de Java", apontou para uma origem asiática, assim como a descoberta de restos humanos antigos na caverna de Zhoukoutien, perto de Pequim (1923-1927), conhecidos como pertencentes ao "Homem de Pequim", e, antes dos dois, a descoberta de restos conhecidos como do Homem de Neandertal (1856), que recebe esse nome devido ao Vale Neander na Alemanha, onde foi descoberto. A visão eurocêntrica predominante do início do século XX foi aprimorada pela descoberta na Inglaterra de uma farsa cuidadosamente elaborada, conhecida como o Homem de Piltdown (1912). A negação acerca da teoria de origem africana continuou até que o crânio de Piltdown foi denunciado como uma farsa em 1953. Logo depois, *African Genesis* (1961) de Robert Ardrey, que li imediatamente após sua publicação, colocou o crânio de Taung de Dart em foco, esclareceu sua importância, e explicou o atraso em seu reconhecimento: "nunca foram encontrados antecedentes fósseis para a criatura de Dart em toda a África".

Mas a afirmação de Dart (1925) de que "o espécime (...) atesta uma extinta raça de macacos intermediários entre antropoides vivos e o homem" ainda era algo muito desafiador para o *establishment* antropológico europeu, sem falar do público em geral. Um viés eurocêntrico significava que uma origem africana para os humanos modernos estava além da imaginação.

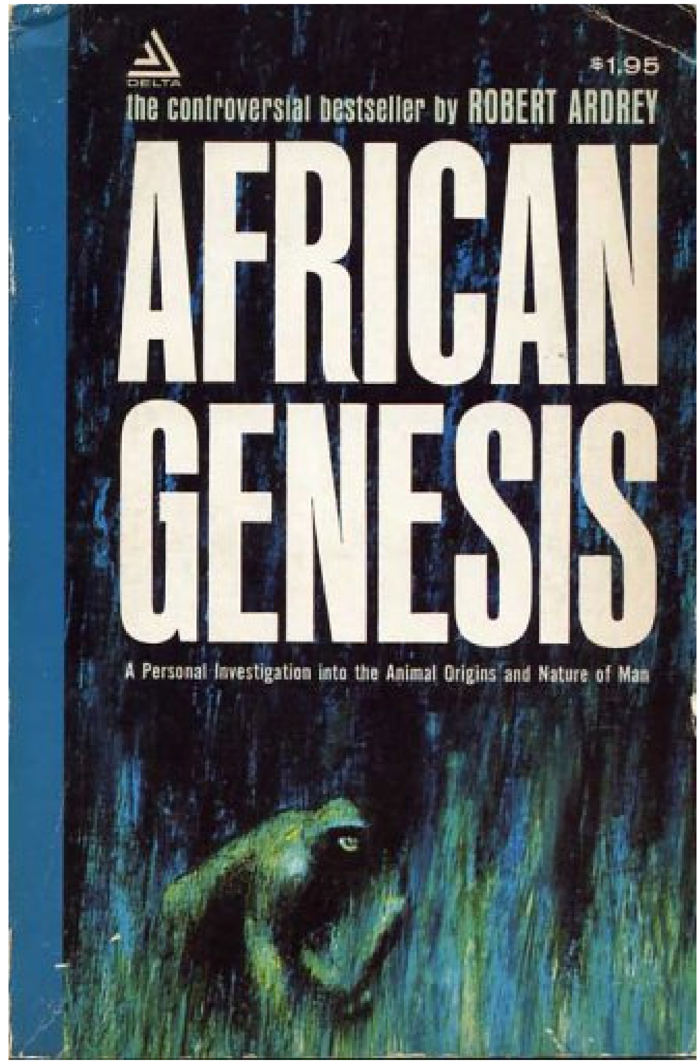

Fig. 1. Robert Ardrey's *African Genesis* (1961) provided the first full treatment of human origins in Africa. The book was a remarkable piece of hobby journalism from a playwright, Hollywood screen writer, and actor on the Broadway stage. Ardrey followed this book with another highly readable contribution in anthropology, *The Territorial Imperative* (1966). Image source: www.amazon.com.

Acumulando evidências da origem africana

African Genesis marcou o início de um novo amanhecer para a teoria antropológica. No quarto de século seguinte apareceram várias confirmações vindas da África Oriental e Central. A mais conhecida foi a descoberta de Donald Johanson no ano de 1974 em Hadar, Etiópia: um hominíneo de 3,2 milhões de anos, *Australopithecus africanus*, mais comumente conhecido como "Lucy". Três anos mais tarde, Mary Leakey descobriu três conjuntos de pegadas de *A. africanus* em Laetoli, na Garganta de Olduvai. Foram feitas por dois adultos caminhando juntos lado a lado, talvez de mãos dadas, e uma criança com passos sinuosos - os três fornecendo um breve vislumbre da vida familiar pré-histórica. As pegadas foram feitas em cinzas vulcânicas transformadas em rochas que datam de 3,7 milhões de anos. Como Raichlen et al (2010) observaram, as pegadas de Laetoli são agora reconhecidas como nossa "primeira evidência direta da biomecânica bípede semelhante à humana". Houve outras descobertas dramáticas o suficiente para eliminar todas as dúvidas sobre a pré-história dos seres humanos na África e para permitir costurar uma pré-história tentativa do *H. sapiens*.

Uma resposta visual para minha velha pergunta secundarista tomou forma quando abri minha edição de outubro de 1988 da *National Geographic*, onde vislumbres fragmentados se uniram em um mapa de "povoamento da Terra" (Fig. 2). A resposta estava gravada em setas saindo da África, traçando migrações humanas para a Austrália, Ásia, Europa e, eventualmente, para as Américas. Datas em milhares de anos em vários pontos do mapa - 96.000 na África do Sul, 50.000 na Austrália, 33.000 na Europa e 12.000 na América do Norte - marcavam o progresso dos seres humanos em seus movimentos em uma paisagem pré-histórica ao longo de seis continentes. Distinções que reconhecemos hoje ainda não haviam sido elaboradas: o mapa misturava migrações muito anteriores do *Homo erectus* com a migração muito posterior do *H. sapiens*; além disso, as setas generalizadas levantaram mais questões. A seta da África para a Austrália passou por Israel, atravessou o Himalaia, em seguida, saltou da terra para a água em Mianmar e seguiu uma rota tardia através do Estreito de Malaca, com um salto final de Java para a Austrália. Como observa Nicholas Wade (2006: 76), desses primeiros mapas de migração, "as setas inevitavelmente dão a impressão de que os imigrantes estavam viajando de propósito para esses pontos distantes (...). Mas na verdade, é duvidoso que eles estivessem em uma jornada." Mas o movimento pelas Américas foi igualmente esquemático - simplificado por uma seta que surgia do Alasca e passava pelo centro do Canadá e das Grandes Planícies americanas, apontando para a América Central e do Sul. Setas que atravessam enormes extensões do Oceano Pacífico levantaram questões sobre embarcações, especialmente desde que Kon-Tiki (1948), o famoso relato de Thor

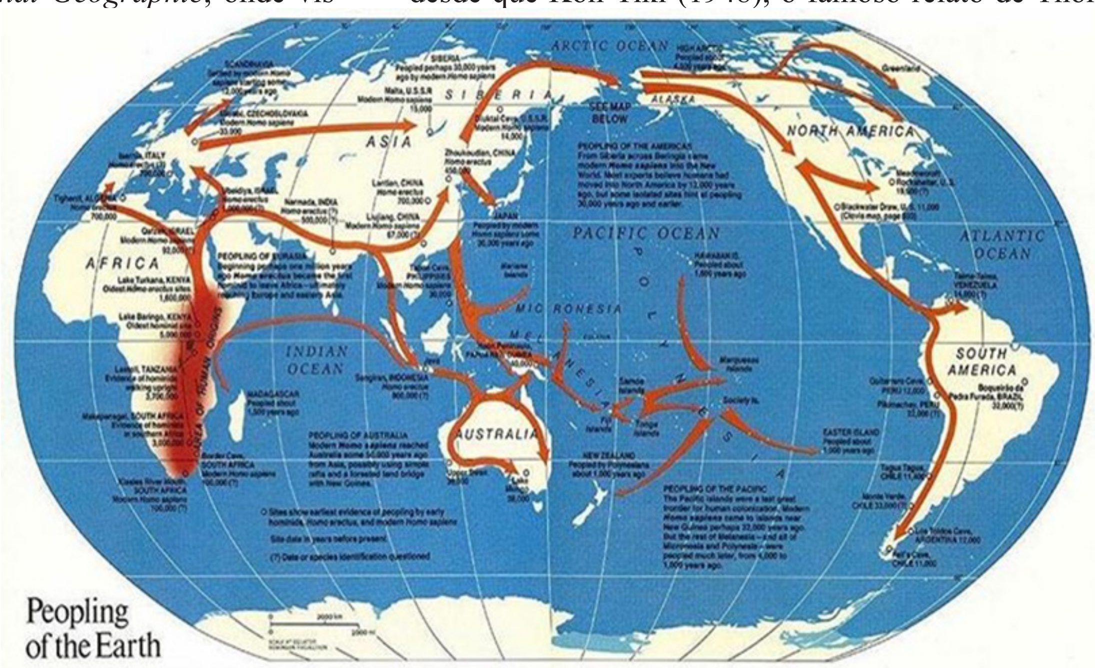

Fig. 2. An early map of prehistoric human migration from "The Peopling of the Earth" issue of *National Geographic*, October 1988. Note the generalized migration routes which are dependent on a limited number of fossil sites. Image source: www.natgeo.com.

Heyerdahl sobre uma travessia do Oceano Pacífico em uma balsa, sugeriu a colonização da América do Sul através do Pacífico; mas a teoria de Heyerdahl não se encaixava nas evidências e estava ausente do artigo da *National Geographic*. A evidência mais firme limitou--se a locais de escavação dispersos, a partir dos quais foram inferidas rotas de migração generalizadas, mas faltaram detalhes da vida pré-histórica na África ou durante a migração subsequente.

Desde o início do milênio, a África como berço do homem moderno, tem sido conhecimento científico estabelecido, tendo 80.000 antes do presente como uma data aproximada para a partida (Oppenheimer, 2003). Dezenas de livros e milhares de artigos ao longo do último meio século acompanharam descobertas de fósseis hominídeos, ocupações de cavernas, ferramentas da idade da pedra e locais de trabalho pré-históricos. A paleoclimatologia esclareceu a ocupação regional em diferentes momentos e a análise genética estabeleceu relações entre as populações humanas em toda a África e além. Muito dessas informações permanece desconhecido, embora uma gênese africana para humanos anatomicamente modernos seja uma noção sólida o suficiente para que saibamos que é ali que a jornada humana começa. Conforme detalhado por Armitage et al (2011) e outros, as evidências são substanciais e a rota costeira primária fora da África está bem determinada. Muitos detalhes dessa jornada são conhecidos por meio de fragmentos de evidências provindas de várias regiões dos outros continentes habitáveis. As rotas que os humanos seguiram no povoamento do mundo foram refinadas, são compreendidas em termos gerais, e podem ser deduzidas conectando-se os pontos que ligam cada sítio arqueológico ao seguinte, embora as vastas regiões interiores da África, Ásia e Europa ofereçam muitos “pontos seguintes” a serem considerados. O resultado é uma rede complexa de possibilidades, com muitos detalhes ausentes, ensejando hipóteses. Apesar de uma corrente imprecisão de detalhes, ao final do século, a África havia sido identificada como o “berço indiscutível dos humanos modernos” (Lewin, 1987a).

A Incubação Sul-Africana

O ideal de uma narrativa unificada, dependente de uma rota de migração claramente definida, é algo valioso e essencial para uma compreensão macro-histórica coerente de como o *H. sapiens* pré-histórico se espalha pelo mundo. Como indica o Prólogo deste artigo, essa pergunta chamou minha atenção por mais de seis décadas. A redação desse artigo me veio como sugestão tirada do título de um livro que resenhei nessa mesma edição do *Journal of Big History*, chamado *Trekking the Shore* (2011); o livro trata dos espaços costeiros em ensaios separados, tendo por base o uso humano dos recursos marinhos em vinte locais diferentes, mas não consegue juntar esses relatos em uma narrativa coerente que transmita a ideia de uma jornada. O volume se baseia em evidências de locais amplamente apartados e, portanto, depende de descobertas e escavações feitas por especialistas em regiões específicas. Em contraste, este artigo sugere uma rota principal de migração através da reunião de pesquisa já existente acerca dessas rotas primárias de migração vindas da África do Sul - uma até a costa da África oriental, ao longo das praias do Oceano Índico, seguidas por uma jornada circum-oceânica ao longo de todo o Oceano Pacífico, terminando na Patagônia. Essa narrativa emergiu devido ao fato de que fontes de alimento terrestres variam da fartura à não existência, enquanto alimentos marinhos são a fonte mais confiável, dos trópicos às regiões do Ártico.

De fundamental importância para essa narrativa é o estabelecimento do ponto de partida dessa migração. A maior parte das descobertas de fósseis de hominídeos pré-históricos, com a exceção do crânio de Taung, foi escavada na África Centro-Oriental: o *Australopithecus* de Louis Leakey, de 1,75 milhão de anos, e as descobertas já mencionadas de Donald Johanson e Mary Leakey. No início dos anos 1990, a teoria de uma origem africana estava segura. Mas enquanto fósseis muitos antigos, de espécies anteriores, eram encontrados na África Centro-Oriental, fósseis de *H. sapiens* dessa região eram raros, ainda que fossem evidentes em outras regiões. Uma descoberta recente na costa atlântica do Marrocos (Hublin et al., 2017) revelou que humanos anatomicamente modernos se expandiram para além das regiões onde as principais descobertas originais se localizam, ou seja, da África Centro-Oriental. Em condições favoráveis, parece que esses humanos modernos antigos possivelmente ocuparam a maior parte do continente africano. Outra descoberta foi feita nesse sítio no Marrocos: a divergência de *H. sapiens* como espécie deve ter ocorrido por volta de 350.000 a 260.000 anos atrás, muito antes portanto dos 200.000 anos que normalmente se assume ser a idade dos humanos como espécie.

Após 200.000 anos antes do presente, entretanto, e pelos 75.000 anos seguintes, há pouca evidência de que *H. sapiens* esteve presente na África ocidental, oriental e setentrional. Petit et al (1999) mostraram que o período conhecido como Estágio Isotópico Marinho Glacial 6 (EIM-6), datado a partir de vestígios de pólen e plâncton em sedimentos marinhos em 195.000 a 125.00 anos no passado, foi um dos mais longos e frios períodos do Quaternário. Sob essas condições, como o geofísico Robert Walter et al (2000) apontou, uma menor pluviosidade transformou regiões florestais em savana, ou mesmo em estepes caso as estações secas fossem extensas. A região de interesse de Walter era a Eritréia na costa africana do Mar Vermelho, mas suas observações se aplicam a toda África oriental. Ao longo do período a maior parte do continente não conseguir suprir recursos florais e de fauna que dessem suporte para a ocupação humana. Alguns refúgios isolados podem ter abrigado pequenos grupos por algum tempo, até que tenham se movido ou sucumbido. Grupos bem sucedidos foram aqueles que gravitaram na direção das bordas estreitas entre a savana e a costa, onde podiam explorar recursos alimentares marinhos.

A evidência para isso vem de sítios de ocupação e de artefatos ao longo da costa meridional da África. Tal como a datação do crânio de Taung sugere, espécies ancestrais estiveram presentes na África do Sul por mais de um milhão de anos. Recentemente, Schlebush et al (2017) chamaram atenção para a região costeira sul-africana como um habitat de importância central na narrativa da emergência dos humanos modernos, onde numerosas cavernas mostram evidência de condições de vida mais adequadas e de ocupação humana mais longeva. Por volta do tempo em que *H. sapiens* emergiu, por volta de 350.000 a 200.000 anos no passado, já haviam adquirido um reservatório genético pan-africano de grande diversidade, vindo de espécies anteriores por pelo menos dois ou três milhões de anos. Surpreendentemente, no entanto, o genoma dos humanos modernos fora da África tem comparativamente pouca diversidade genética, sugerindo que linhagens humanas modernas não africanas passaram por um gargalo genético em algum momento de sua trajetória. Uma população limitada – um grupo reprodutivo de foco regional, cuja diversidade periférica tenha sido eliminada pela concentração territorial - parece ter formado as populações fundadoras subsequentes de *H. sapiens* fora da África. Antropólogos e geneticistas (Fagundes et al., 2007; Gonder et al., 2007; Benhar et al., 2008) descreveram e dataram esse gargalo no Estágio Isotópico Marinho Glacial 6, logo posicionando-o no mesmo período em que ocorreram os assentamentos sul-africanos aqui descritos.

O distinto ecossistema sul-africano, especificamente a Região Floral do Cabo (CFR) é crucial para sua importância. O CFR é um dos mais ricos e acolhedores ambientes onde a população majoritária de *H. sapiens* viveu durante o EMS-6, desse modo provendo uma incubação estendida para a aquisição e desenvolvimento de competências de sobrevivência tanto físicas quanto cognitivas. A região ocupa uma área aproximadamente de 200 a 400 quilômetros, para uma área oficial de 78,555 $km^{2;}$; é um dos dois “Reinos Florais” do planeta, tão rico em espécies de plantas que é hoje uma das regiões de conservação prioritária de ecossistemas incluída na iniciativa Global 200, e designado como Patrimônio Mundial da UNESCO em 2004. Com variações em altitude representadas por vales, colinas e montanhas, inclui três regiões climáticas, centenas de espécies florais, e uma rica gama de

Fig. 3. The Cape Floral Region of South Africa, noted for exceptional temperate biodiversity, is home to 9000 species of plants, sixty percent of which are endemic to the region. The coast is populated with five tortoise species specific to the region, along with seals, seabirds, penguins, and antelope. Human occupation in more than twenty caves extends through the entire 200-thousand-year history of *Homo sapiens*. Image source: whc.unenesco.org.

pássaros costeiros e mamíferos.

Nesse ecossistema estiveram disponíveis numerosos tipos de raízes comestíveis, tubérculos, bulbos e colmos (geófitos); apropriadamente, o antropólogo Curtis Marean (2012) descreveu a região como uma "cornucópia costeira". São importantes para nossa história os inúmeros refúgios rochosos e cavernas ao longo da costa, alguns com espetacular vista para o Oceano Índico. Neles encontramos evidência de ocupação que se estende desde espécies hominíneas ancestrais ao *H. sapiens* em 200.000 anos antes do presente, com acesso a recursos alimentares marinhos diversificados. A população total dessa região pode ter permanecido inferior a 10.000 habitantes; a gama de possibilidades demográficas calculada por Fagundes et al (2007) indica que a população pode ter sido tão pequena quanto 600 habitantes, um montante marginal para qualquer espécie, o que sugere que *Homo sapiens* poderia ter terminado como uma dúzia de espécies hominíneas anteriores e extintas.

A despeito do confinamento climático e ambiental a essa região, a evidência de uma estratégia de sobrevivência e de avanço cognitivo vindas dessa população é de fato notável. Nuno Bicho et al (2011: xix) notaram que "recursos alimentares costeiros são raramente transportados mais que dez quilômetros para o interior e a maior parte da evidência [na África do Sul] foi acumulada entre 2-4 quilômetros". Na Região Floral do Cabo, mais de duas dúzias de cavernas ou complexos de cavernas a esta distância da costa oferecem registros sistemáticos de ocupação humana, cultura, tecnologia, e de coleta de frutos do mar. Uma mistura complexa de conquistas culturais emergiram ali: vários tipos de ferramentas líticas cortantes, implementos de osso, e os primórdios da ornamentação pessoal na forma de conchas perfuradas, obviamente usadas para compor colares de contas. Ferramentas têm sido encontradas em sítios interioranos como Cooper's Cave (Berger, 2003). Fragmentos de recipientes para água, feitos com ovos de avestruz engravados, datando de 65.000 a 55.000 anos atrás, foram encontrados em Diepkloof Rock Shelter. Pierre-Jean Texier (2010), que fez a descoberta, nota que as gravuras parecem ter sido feitas para serem mostradas, talvez indicando uma conexão comunal, sendo resistentes o suficiente para que servissem como cantis usáveis mesmo estando distantes das fontes de água. Brown et al (2009) decifraram a tecnologia que emprega o fogo como forma de endurecer material lítico para a confecção de ferramentas em Pinnacle Point, uma tecnologia de 195.000 a 90.000 anos no passado. Essas e outras inovações práticas e decorativas podem ser consideradas *proxies* de um aumento na competência linguística, simbólica e cognitiva do *H. sapiens*.

Quando vasta arte rupestre na Europa é descoberta em Altamira e Lascaux, é considerada uma evidência de um salto na capacidade cognitiva em torno de 40.000 anos atrás, talvez estimulada pelos desafios da Era do Gelo, responsáveis pelas habilidades fundamentais da civilização e cultura modernas - e talvez também pela dominância de *H. sapiens* sobre os Neandertais, o que levou à sua extinção nessa época. Essa ênfase também aparece em *The Roots of Civilization* (1972), a extensa análise de ossos gravados feita por Alexander Marshack com seu conceito de "arqueologia cognitiva", em que artefatos antigos são examinados como *proxies* para o desenvolvimento cognitivo. Por mais ricas e sugestivas que fossem essas observações, as realizações artísticas, decorativas e tecnológicas na África do Sul sugerem que um salto na cognição humana e nas habilidades imaginativas ocorreu mais de 100.000 anos antes.

A coleta de frutos do mar pelos ocupantes das cavernas do rio Klasies (Thackeray, 1988) e da caverna 13B de Pinnacle Point (Marean, 2007, 2011) sugere uma explicação dietética para esse aumento: antropólogos nutricionais argumentaram que a coleta contínua durante o EMS-6 aponta para frutos do mar e moluscos como fontes de ácidos graxos não produzidos pelo corpo humano que, no entanto, são fundamentais para o desenvolvimento do cérebro (Cunnane et al., 1993; Crawford et al., 1998; Broadhurst et al., 2002). A colheita de frutos do mar a longo prazo por um período de pelo menos 70.000 anos pode ter fornecido o estímulo nutricional instrumental para o desenvolvimento dramático da cognição que caracterizou os seres humanos durante a migração subsequente, e que exigiu múltiplas adaptações à medida que levou adiante o povoamento do planeta.

Em paralelo ao reconhecimento da África do Sul como uma região de incubação nutricionalmente rica para o *H. sapiens*, estudos de DNA mitocondrial (mtDNA), um marcador que é exclusivo da genealogia feminina, atestam uma origem sul-africana para os seres humanos no ponto em que partem para explorar o mundo (Lewin, 1987b). Rebecca Cann et al. (1987) mostraram que toda a família humana remonta a uma "mãe sortuda" ancestral (popularizada como a "Eva mitocondrial"), que vivia em algum lugar da África subsaariana. A calibração recente de genomas mitocondriais antigos por Fu et al (2013) sugere sua data em torno de 160.000 anos atrás. Dentro de sua linhagem, o Haplogrupo LI / L0 deu origem sucessivamente a L2 e L3 por volta de 80.000 anos atrás, todos "enraizados profundamente na África Subsaariana com ramificações derivadas fora dela" (Oppenheimer, 2012). Atkinson et al. (2008, 2009) identificam o Chifre da África como o ponto de origem tardio para o haplótipo L3, que é a fonte dos ramos genéticos derivados M e N, encontrados em todos os não africanos: a datação por carbono indica M e N como tendo sido originados entre 69.000 e 50.000 antes do presente. Inúmeras linhas de inferência atestam esse intervalo de datas.

Jornada para fora da África

O aquecimento climático que se inicia quando EMS-6 chega ao fim, sem dúvida, abriu um caminho para o movimento de seres humanos em direção ao norte, vindos da África do Sul. Possíveis pontos de partida – cavernas ocupadas – que se estendem ao longo de mais de 400 km da costa sul-africana levariam logicamente a inúmeras rotas de migração para o interior. No entanto, as regiões áridas do deserto do Saara reduziriam ou redirecionariam algumas rotas, embora um caminho pelo distrito dos lagos do vale do Rift, ao norte, proporcionasse uma passagem desobstruída para terras setentrionais. Também aqui, como Broadhurst (1998) mostrou, peixes lacustres e mariscos do vale do Rift forneceriam benefícios nutricionais semelhantes para o desenvolvimento cognitivo, da mesma forma que os frutos do mar na costa sul-africana. Uma passagem para o vale do rio Nilo se seguiria, levando finalmente à costa do Mediterrâneo.

O primeiro movimento do *H. sapiens* para fora da África parece ter ocorrido no Vale do Nilo, talvez a partir do delta do rio. Vestígios fósseis datados em Israel mostram que um pequeno grupo vindo do que agora é o norte do Egito seguiu para o nordeste, mas evidentemente não avançou além da Caverna Skhul, nas encostas do Monte Carmelo (Wells 2006: 116-117). A evidência de ocupação ali e em Qafzeh data de 110.000 anos atrás. Steven Olson (2002: 75) mapeia uma rota provável através do Sinai e do norte em direção a Israel, o que sugere o Vale do Nilo como o mais provável caminho vindo do sul. No entanto, as evidências dessa migração precoce não se estendem além de Israel. O tamanho deste grupo não pode ser determinado. Era evidentemente numeroso o suficiente para deixar vestígios por vários milênios, mas declinou, se tornando pequeno demais para se sustentar, e foi extinto por volta de 70.000 anos antes do presente e, portanto, representa uma migração de rebote, de pouco interesse para o povoamento do mundo.

Mais de cem milênios da vida costeira da África do Sul, com uma dieta de frutos do mar, fornece uma explicação para a ocupação humana muito tempo depois da saída de alguns grupos migrantes. No entanto, a aventura nunca deve ser esquecida: a migração não forçada para o norte, na costa oriental mais quente do continente, era praticamente inevitável. Muitos anos atrás, Carl O. Sauer (1962) sugeriu que as praias da África forneceriam o melhor ambiente para os seres humanos primitivos – livres dos caprichos das variações climáticas internas e rico em recursos marinhos. Spenser Wells, autor de *The Journey of Man* (2002) e narrador do vídeo homônimo, defendeu a migração costeira: "A rota costeira seria uma espécie de via expressa pré-histórica, permitindo um alto grau de mobilidade sem exigir adaptações complexas a novos ambientes que seriam necessárias em uma rota interior". Embora tenha sido escrito a partir de um entendimento com base na África costeira, ele se aplica a regiões muito além: "devido à facilidade de movimento proporcionada pela costa, essa rodovia arenosa que circunda os continentes, isso permitiria migrações relativamente rápidas. Nenhuma cadeia de montanhas ou grandes desertos a atravessar, nenhuma necessidade de desenvolver novas ferramentas ou roupas de proteção e nenhuma flutuação drástica na disponibilidade de alimentos" (Wells, 2002: 69).

É concebível que vários grupos migratórios possam ter seguido a costa leste da África, com acesso contínuo a frutos do mar, incentivando assentamentos de curto prazo ao longo do caminho. Tais migrações dependeriam da experiência de coleta de frutos do mar acumulada por milênios no cabo meridional. Apesar da facilidade representada por essa "superestrada" costeira, o progresso pode não ter sido célere, considerando o estabelecimento de uma série de assentamentos costeiros temporários, embora isso continue sendo apenas uma conjectura sem evidências materiais específicas. É improvável que os migrantes costeiros tenham renunciado inteiramente a alimentos florais e geófitos a poucos quilômetros da costa, mas a abundância e a confiabilidade dos recursos de frutos do mar favoreceriam a coleta nas praias e alguns assentamentos costeiros semipermanentes. Essa rota costeira seria limitada a um corredor estreito definido por essas fontes alternativas de alimento. Apesar dessa limitação, os traços de migração ainda são improváveis, e de fato se furtam à descoberta; como disseram Nuno Bicho et al. (2011: xv), as zonas litorâneas antigas foram inundadas pelo aumento do mar causado pelo aquecimento climático pós-glacial. Evidências na forma de ferramentas, fogueiras ou pilhas de descarte podem ter existido em praias pré-históricas, que agora estão a até 100 metros debaixo d'água.

Mas enquanto faltam evidências materiais da migração pela costa leste africana, surgem recentemente evidências genéticas para ela. Em um levantamento sobre forrageadores, agricultores e pastores da África do Sul, Malaui e Quênia, que viveram entre 400 e 3.100 anos atrás, Pontus Skoglund et al (2017) revelaram evidências de um muito antigo e "até então desconhecido" grupo pré-agrícola de "populações de caçadores-coletores que se estenderam da Etiópia à África do Sul". David Reich, um dos investigadores participantes do estudo de Skoglund, refere-se a eles como uma "população fantasma" de forrageadores que outrora dominaram a costa leste da África Subsaariana, a quem dá o nome de "Forrageadores da África Oriental" (Reich, 2018: 221). O estudo estabelece que guardam uma relação mais próxima com os não africanos do que com qualquer outro grupo populacional na África. Essa população fantasma, que por si só era uma complexa mistura de grupos de forrageadores, pode ser (ou pode estar relacionada a) coletores migrantes da África Oriental que partiram da Região Floral da África do Sul, e cujos descendentes eventualmente migraram para fora da África.

Uma rota costeira pela África Oriental é evidenciada para além do Chifre da África, onde os humanos modernos cruzaram a extensão de água entre a África e a Península Arábica em Babelmandêbe, o "Portão das Lágrimas". Esses migrantes carregavam o DNA mitocondrial profundamente enraizado de uma mulher (mtDNA) e o cromossomo Y de um ancestral masculino, juntamente com um marcador genético que definiu um haplogrupo único, neste caso o Haplogrupo M (Wells, 2006: 180-182). Esse marcador permite traçar a coleta costeira e os assentamentos do *H. sapiens* além da África - através do sul da Arábia, Omã e Emirados Árabes Unidos, sul da Ásia em direção ao Paquistão e norte da Índia (Wells, 2006: 180-182). As evidências indicam que o ambiente na costa sul da Arábia era mais agradável do que agora, possibilitando o progresso que levou os humanos modernos ao sul da Ásia, Austrália e costa da China.

Embora essa travessia pelo Mar Vermelho pudesse ser feita a partir do interior do Vale do Rift, na África – e pode muito bem ter incluído um contingente de migrantes vindos através dele –, era também o término lógico de uma rota costeira pela África Oriental. Vincent Macaulay et al (2005) caracterizaram a travessia para a Arábia como uma "colonização costeira da Ásia rápida e única", que podemos supor corresponder a um nível do mar favorável, a um evento climático favorável ou mesmo um a grupo particularmente entusiasmado de líderes venturosos. Independentemente do motivo pelo qual se deu esse avanço, aqueles que fizeram a travessia parecem ter formado um grupo de composição genética coerente, que carregava apenas uma parte da riqueza genética da população africana deixada para trás. Esse conteúdo restrito fornece um caminho para estimarmos quantos migrantes fizeram a travessia: conforme relatado por Nicholas Wade (1997), a antropóloga Sarah Tishkoff da Universidade de Maryland estima um grupo com 200 a 500 migrantes, mas Wade subsequentemente su-

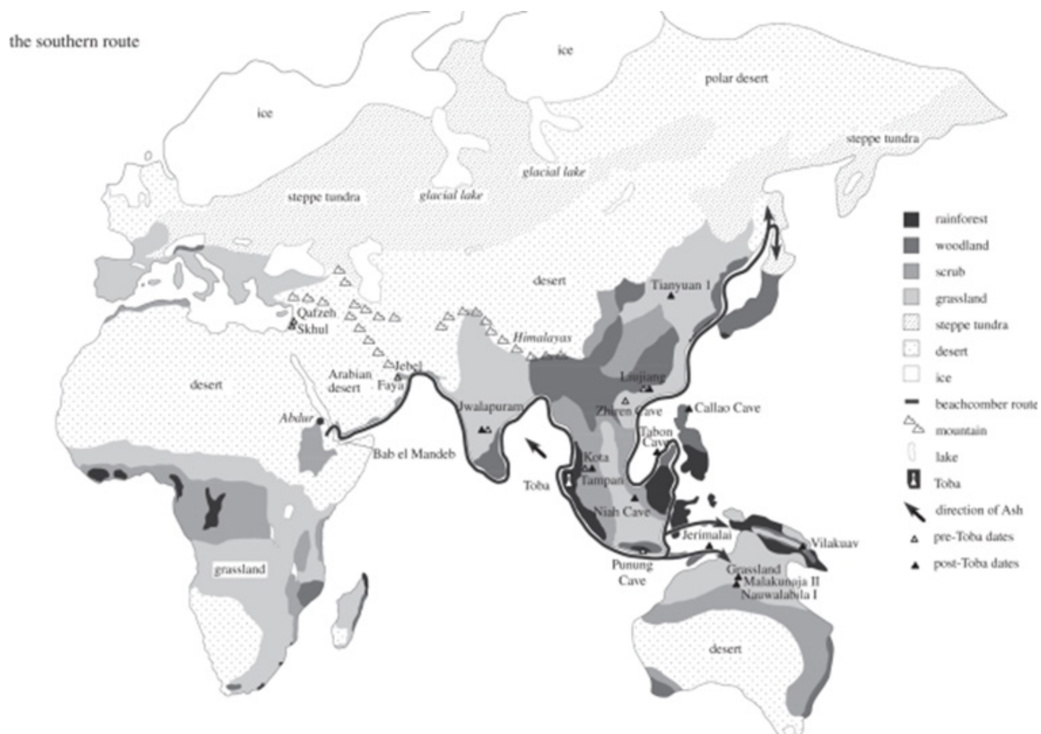

Figure 4. The crossing of the Red Sea from Africa to Arabia at *Bab el Mandab* marks the beginning of what is now called the Southern Dispersal route. The resulting coastal route follows the vast circuit of South Asian beaches on the Indian Ocean through India and Indonesia, then heads north from Indonesia, to the Philippines, China, Taiwan, Korea, Japan, and the Pacific coast to Siberia. Oppenheimer (2012) calls it the "beachcomber route." Image source: www. royalsocietypublishing.org.

geriu apenas 150 (2006: 81).

Até recentemente, esse travessia foi datada de 70.000 e 60.000 anos atrás, mas Armitage et al. (2011) sugeriram que a migração pelo sul da Arábia pode ter ocorrido durante os milênios finais do EMS-6, de 130.000 a 125.000 anos no passado. Durante esse máximo glacial, o nível do mar era mais baixo e a largura do estreito de Babelmandêbe era mais estreita, permitindo o movimento de uma população substancial, evidentemente nunca em perigo de extinção. Esta data mais precoce é suportada por ferramentas líticas encontradas em leitos de rios nas montanhas Dhofar, no sul de Omã (Groucutt, 2018), que datam de mais de 100.000 anos atrás (Underwood, 2011), ilustrando um kit de ferramentas de lâmina microlítica anteriormente conhecido apenas no Sudão. J.I. Rose (2007) se referiu a isso de maneira divertida como "uma trilha de migalhas de pão de pedra", do Sudão à Arábia. A datação precisa da primeira ou mais recente partida da África ainda não foi determinada, mas evidências arqueológicas e genéticas indicam que essa migração pela Arábia e para as costas do sul da Ásia foi pioneira, em oposição a uma partida através do norte pelo Sinai.

Wade (2006: 75) fornece um mapa que marca claramente a rota costeira da África para a Austrália, mas essa rota, agora conhecida como Rota de Dispersão Meridional, gira para o norte nas ilhas da Indonésia e continua pela costa leste da Ásia até a Sibéria (Figura 4) e para as Américas. Hoje, o nível mais alto do mar ao longo das costas do Iêmen, Omã e Emirados Árabes Unidos oculta as condições costeiras que existiram ao final do EMS-6 e início do EMS-5; como Faure et al. (2002) apontam que, quando o nível do mar é mais baixo, as fontes de água doce aparecem nas plataformas continentais emergentes – resultado de um declive acentuado em gradiente dos aquíferos interioranos - fornecendo uma fonte de água para os migrantes costeiros. Um segmento interessante da série de vídeos *The Incredible Human Journey* (Roberts, 2009), mostra Alice Roberts, com J.I. Rose, em um barco na costa sul da Arábia, com Rose explicando a disponibilidade de água doce das nascentes, agora submersas pela elevação do nível do mar. Regiões de vegetação costeira associadas a essas fontes ao longo do litoral sul da Arábia facilitaram o trânsito para o sudeste da Arábia, onde escavações em Jebel Faya, nos Emirados Árabes Unidos, indicam uma possível ocupação de 130.000 anos atrás.

A chegada à embocadura dos rios Tigre e Eufrates, que deságua no Golfo Pérsico, pode muito bem ter representado uma escolha importante, pois essas foram as primeiras e principais fontes interioranas de água doce encontradas pelos migrantes provenientes da Dispersão do Sul. Voltaremos a isso mais tarde, observando aqui que esse pode ter sido um ponto de decisão primário em que alguns migrantes escolheram rios fluviais do interior em vez de costeiros, tornando-se a população fundadora no interior da Ásia e da Europa.

As evidências provindas do sul da Ásia indicam que a jornada costeira continuou, provavelmente ao longo das praias agora submersas do que hoje é Kuwait, Iraque, Irã e Paquistão até o sul da Índia. A costa ocidental da Índia é escassa em evidências materiais. Aqui, como na costa leste da África, o nível do mar de 100 a 110 metros (300 a 400 pés) abaixo do nível atual significa que as praias pré-históricas estão agora submersas - em alguns casos ao longo da costa oeste da Índia, em até 200 km mar adentro. As praias seguidas pelos migrantes coletores de frutos do mar estão agora embaixo d'água, e com elas evidências de assentamentos temporários e intermediários levados pelas marés altas. No entanto, a migração ribeirinha aponta para o rico sítio arqueológico do sul da Índia em Jwalapuram, interior do rio Krishna. Aqui, ferramentas de pedra de micro-lâmina análogas às dos antecessores africanos estendem a "trilha de migalhas de pão de pedra" que começou no Sudão. Sítios indianos fornecem evidências cronológicas: a chegada do *H. sapiens* à Índia subcontinental ocorreu após um evento geológico confiavelmente datado. Por volta de 74.000 anos atrás, o vulcão do Monte Toba, no norte de Sumatra, entrou em erupção no que é hoje reconhecido como o evento vulcânico mais violento do Pleistoceno. Vestígios são evidentes em todo o sudeste da Ásia e na Índia a milhares de quilômetros de distância. Como documentaram Petraglia et al (2007) , a tecnologia lítica de microlâminas é evidente em Jwalapuram logo após o evento de Toba.

Este assentamento interior estendido em Jwalapuram aponta para uma característica das rotas de migração que decorrem de aspectos profundos do comportamento humano. As pessoas naturalmente se dividem em grupos separados: colonos satisfeitos e exploradores aventureiros. Muitos anos atrás, os antropólogos R.B. Lee e I. DeVore (1968: 245-249) calcularam um tamanho médio para um grupo de caça e forrageamento em cerca de trinta indivíduos, que eles chamaram de "número mágico" para manutenção das populações e para o compartilhamento de tarefas cooperativas. Em um ambiente costeiro rico em recursos, um grupo de trinta ou mais membros pode subsistir indefinidamente em um local conveniente perto da água doce. Mas os ricos recursos marinhos e os benefícios nutricionais de um ambiente costeiro logo levariam ao aumento da população, elevando a população em alguns anos a quarenta, ou mesmo cinquenta indivíduos no espaço de uma geração. Esse aumento proporcionaria, assim, uma motivação para a fragmentação dos grupos. Os colonos satisfeitos podiam ficar para trás enquanto os aventureiros avançam, e alguns podiam escolher uma rota fluvial para o interior. Assim, como Wade escreveu, "em um século – cinco gerações – uma sociedade de caçadores-coletores poderá se espalhar por uma distância considerável (...) Essas migrações de longa distância (...) não foram feitas por um único grupo em uma longa jornada, mas foram a lenta expansão das populações humanas que levaram uma geração para percorrer cada trecho da jornada (...) O mundo seria ocupado de maneira bastante ordenada"(2006: 77-78). Ao longo de muitas gerações, os colonos desenvolveriam marcadores genéticos localizados, enquanto os aventureiros desenvolveriam novos marcadores que podem ser rastreados através de assentamentos posteriores ao longo de rotas de migração estendidas. Assim, as mutações genéticas fornecem uma "memória" permanente do movimento humano que pode ser descoberta pela análise de DNA de povos indígenas estabelecidos há muito tempo.

Migração costeira além da Índia

Em algum lugar a leste da Índia, uma única rota costeira parece ter se bifurcado em duas. Uma seguia para o sul através do leito exposto da Baía de Bengala até as Ilhas Andaman, saltando para as Ilhas Nicobar, Sumatra e Sudeste da Ásia. A eficácia desta via ficou clara a partir da análise genética dos ilhéus de Andaman, uma população relicta que tem ocupado o arquipélago por milênios (Thangaraj et al., 2003, 2005). A outra seguiu a costa de Bangladesh, Mianmar, Tailândia e Península Malaia até a Ilha Indonésia, onde populações concebivelmente separadas eventualmente se fundiram. Toda a complexa história da migração para o Sudeste Asiático é contada em uma apresentação revisada de Peter Bellwood (2017).

A migração costeira no sudeste da Ásia era muito mais complexa e, em última análise, mais desafiadora do que as caminhadas costeiras na África ou no sul da Ásia, que apresentam menos ilhas marítimas. Inicialmente, o sudeste da Ásia era mais peninsular do que insular: o nível do mar reduzido transformou o fundo do mar entre Bornéu, Java, Malásia e Sumatra em uma planície de ligação (chamada Sunda), uma mistura de zonas úmidas e manguezais que não existem mais; numerosas terras uma vez unidas agora estão separadas. Ao mesmo tempo, grande parte da atual Indonésia a leste de Bornéu permaneceu isolada, o que tornava o prosseguimento da migração um desafio significativo, representado pela necessidade de cruzar o mar. Uma barreira oceânica separava Bornéu de Sulawesi e Nova Guiné, impedindo a migração animal – algo evidente na linha divisória biológica observada por Alfred Russell Wallace (a Linha Wallace). Essa divisão oceânica isolou a Nova Guiné e as regiões sul e, portanto, confinou a fauna australiana a um caminho evolutivo distinto. Mas aquilo que separou animais não impediu que humanos mais empreendedores fizessem a travessia.

Por duas décadas esqueletos encontrados no sítio do Lago Mungo em Nova Gales do Sul sugerem que 42.000 anos atrás é a data de referência para a chegada dos humanos modernos na Austrália (Thorne, 1999). No entanto, em Madjedbebe, um abrigo rochoso no norte da Austrália, uma série de escavações progressivamente mais refinadas (1973, 1989, 2012, 2015) exibiram lascas de silcreto, ocre moído, uma pedra de moagem e mais de 12.000 artefatos de pedra. Métodos avançados de datação resultaram em uma idade muito anterior - 65.000 anos atrás (Clarkson, 2017) – uma data que define um piso temporal para a partida da África, e uma janela de chegada estreita entre 65.000 e 74.000 anos para a chegada à Índia e regiões próximas à erupção de Toba.

Hoje, o Sudeste Asiático é uma terra de ilhas: os arquipélagos de Andaman-Nicobar têm 572 ilhas, a Malásia tem 878, Indonésia 18.307, Filipinas 7.641, e apesar da impressão de que a Austrália é composta por uma grande ilha, existem 8.222 ilhas no interior de suas fronteiras marítimas. Esse total surpreendente de mais de 35.000 ilhas constitui uma razão na proporção entre zonas costeiras e não costeiras que torna a coleta nas praias oportunidade dominante no forrageamento, e as migrações mais recentes quase sempre foram costeiras.

Consideremos que os migrantes da África seguiram em direção à Arábia carregando o marcador genético M. Uma variante, M 168, surgiu no nordeste da África, atravessou o Portão das Lágrimas até a Arábia e acabou se tornando o ancestral dos migrantes do interior do norte da Eurásia (Wells, 2002: 73). Então, em algum lugar ao longo da rota costeira do sul da Ásia, provavelmente após 75.000 anos atrás, um indivíduo nasceu com outra variante, dando origem a M 130. As viagens de M e M 130 formam o enredo de uma narrativa costeira que delineia a chegada dessas populações ancestrais: a presença de M 130 vai aumentando de 5% entre os Adi e Negritos da Índia e das Ilhas Andaman, para 10% entre os Orang asli ("Povo Original") na Malásia, para 15% em tribos originais na Nova Guiné e 60% entre os aborígines australianos. M1 é encontrado em 20% dos tipos mitocondriais na Índia e em quase 100% na Austrália (Wells, 2002: 72-74). Após os desafios da travessia marítima de Bornéu para a Nova Guiné, a migração para o sul em direção à Austrália apresentou poucos desafios. O nível mais baixo do mar havia exposto uma extensão considerável do fundo do mar – outra área geográfica pré-histórica agora conhecida como Sahul. A migração pela costa ao longo de suas praias ocidentais levaria ao norte da Austrália central, à região do já mencionado abrigo rochoso de Madjedbebe, perto da costa (Clarkson, 2017).

Datas agora bem atestadas fornecem uma cronologia para a narrativa de dispersão pelo sul ou a chamada rota dos "coletores praianos" de Oppenheimer: uma partida da África entre 120.000 e 80.000 anos atrás; a presença na Índia em torno de 74.000 anos atrás; a chegada à Austrália por 65.000 anos atrás. Com a chegada subsequente dos aborígenes Palawa na Tasmânia, aproximadamente 40.000 anos atrás, um deslocamento costeiro de trinta a oitenta mil anos havia então conduzido os humanos ao limite migratório espacial do mundo. Enquanto isso, um litoral mais longo ainda não havia sido descoberto – uma rota pelo norte que levaria aventureiros humanos em uma migração ainda mais longa, finalmente para as terras mais remotas, terminando na maior jornada já feita.

Jornada pelas Praias do Leste Asiático

Migrações para o norte ao longo da costa da China são quase certas, dada a distribuição de marcadores genéticos ao longo da costa do leste asiático. Capelli et al (2001) mostraram que o Haplogrupo O3-M122 (ADN-Y) ("M" mostrando continuidade com a rota costeira para fora da África) é encontrado entre chineses, filipinos, vietnamitas, taiwaneses e coreanos. Além disso, o Haplogroupo 01a-M119 fornece uma ligação adicional entre filipinos e taiwaneses. Chang et al (2002) mostraram que outros marcadores genéticos são comuns entre tailandeses, chineses, indonésios e filipinos. Parece claro que alguns migrantes da rota de dispersão sul se moveram para o interior da Tailândia através do Laos, para o Vietnã e o sul da China, onde vários locais de assentamentos no interior atestam a presença do *H. sapiens* (Olsen et al., 1992). Mas o ramo de migrantes do sul que se deslocou pela Península Malaia através de Sunda em direção a Bornéu acabou levando os marcadores genéticos do Sudeste Asiático por uma rota indireta para o litoral leste da Ásia. O rastreamento da rota de migração de marcadores costeiros e haplogrupos é difícil, no entanto, porque uma plataforma continental rasa na costa da China significa que assentamentos temporários, locais de trabalho pré-históricos e recursos marinhos estão agora a muitos quilômetros da costa, inundados e destruídos pelas águas oceânicas.

Ilhas em alto mar e arquipélagos, no entanto, são *proxies* para a continuidade costeira. A ilha de Palawan, que se estende diagonalmente por 280 km entre Bornéu, a sudoeste, e Mindanau, a nordeste, é um exemplo. Durante o movimento do *H. sapiens* no Sudeste Asiático, quando o nível do mar estava mais baixo, Palawan esteve conectada a Bornéu, fornecendo uma rota de migração que é atestada pela descoberta de restos humanos em 1962 e por extensos locais de trabalho para ferramentas no complexo da Caverna Tabon, de 47.000 anos de idade. Por mais de meio século, Palawan foi celebrada como o berço da civilização filipina. Apesar do oceano intermediário entre Palawan e Mindanau, Palawan é o ponto de partida lógico para a migração para as Filipinas, que na época era uma única massa de terra que se estendia na direção norte-sul por 1500 km. A subsequente elevação do nível do mar transformou essa extensão de terra em um arquipélago de 7.641 ilhas. Mais recentemente, Henderson et al (2007) relataram a descoberta de um osso do pé proveniente de *H. sapiens* nas Cavernas Callao, na extremidade norte das Filipinas, que substituiu as descobertas da Caverna Tabon, fazendo retroceder a ocupação de Homo sapiens para 67.700 anos no passado.

O efeito mais dramático de um nível do mar até 120 metros mais baixo do que o atual foi a exposição de todo o fundo do mar do Estreito de Taiwan. A uma distância de 130 km, a Taiwan atual está fora do alcance visual de alguém na China continental, mas durante os tempos glaciais o fundo do mar exposto formava uma conveniente ponte terrestre através da qual outras espécies animais bem como o *H. sapiens* costeiro puderam atravessar. Em 1972, fósseis humanos foram descobertos no distrito de Zuozhen, na costa nordeste de Taiwan, incluindo fragmentos cranianos e um molar. Os avanços científicos permitiram a datação do "Homem de Zuozhen" entre 20.000 e 30.000 anos de idade (Liu, 2009). O acesso ao Japão a partir do continente também foi relativamente fácil a partir Coréia pelo sul, ou a partir da Sibéria pelo norte, principalmente quando o nível mais baixo do mar reduziu as distâncias em relação ao continente. A análise por Carbono 14 de fósseis de três cavernas no Japão – Yamashita, Sakitari e Shiraho-Saonetabaru – resultaram em datas concordantes de 32.000 a 27.000 anos (Ma-

Figure 5. Bone needles made from the dense foreleg bones of horses or other hooved mammals display acquired skills of carving, smoothing and drilling. Caches of bone needles carbon dated to c. 35,000 BP have been found at several north European and Asian locations. Traveling, hunting, and dwelling in Arctic regions depended on the ability to fashion skin-tight clothing—shirts, pants, parkas, boots, and gloves. Image Source: Gilda Lyons. www.gildalyons.com.

tsu'ura, 1999; Nakagawa, 2010; Shinoda, 2017), enquanto um extenso local de matança de elefantes pré-históricos – parte da caça mundial à megafauna que parece ter levado-a à extinção – fornecem evidências da presença humana já em 40.000 anos atrás.

Da Sibéria para as Américas

Hoje sabemos que os humanos modernos chegaram ao sul da Sibéria há 40.000 anos. Uma rota óbvia seguiria a partir da separação costeira do sul da Ásia, com os migrantes ribeirinhos dos rios Tigres-Eufrates forçando passagem para o norte através da brecha entre o Mar Negro e o Mar Cáspio em direção à Ásia Central. Todas essas sistematizações das rotas de migração devem ser qualificadas considerando-se que a movimentação pode ter se dado em apenas alguns metros por ano em média, e exigiria inúmeras adaptações a novos ambientes, variações climáticas e uma mudança gradual de fontes de alimentos florais para fontes animais. As evidências ao longo do caminho atesta a aquisição de habilidades de sobrevivência eficazes, incluindo os notáveis abrigos feitos de osso de

Figure 6. Beringia is the geographical name for the "land bridge" between Siberia and Alaska. With sea level 100 to 120 meters lower than today, extensive regions of continental shelf were above sea level, rich in flora and fauna, and thus a suitable habitat for prehistoric *Homo sapiens* who settled here for 10,000 to 15,000 years, a period known as the Beringia Standstill. Image source: www.pinterest.com.

mamute encontrados na Ucrânia nos vales do Don e do Dniepr (Iakovleva e Djindjian, 2005). A expansão das migrações para a extensão gelada, a algumas centenas de quilômetros das geleiras da Era do Gelo, pode ter levado de 20.000 a 30.000 anos e milhares de gerações.

Invenções tecnológicas adicionais tornaram possível a sobrevivência nas regiões mais frias do planeta. Entre as principais está um kit de ferramentas de caça - lanças e lâminas de corte; conjuntos de agulhas ósseas de 35.000 anos, encontrados no norte da Eurásia, testemunham o domínio da costura e da confecção de roupas impermeáveis necessárias para a sobrevivência nos climas árticos, tornando a agulha uma das invenções transformadoras da humanidade.

Invenções tecnológicas adicionais ocorreram na época do Último Máximo Glacial, 25.000 anos atrás, com o surgimento de uma tecnologia de microlâminas nas regiões de Altai e do Lago Baikal (Goebel, 2002; Kuzman et al., 2007) - primeiro bifaces e depois as microlâminas úteis para a sobrevivência em regiões árticas, onde a caça de grandes animais era a principal fonte de alimento. Uma sequência semelhante de tecnologia de microlâminas é evidente alguns milênios depois no Japão e no Lago Ushki na Península de Kamchatka (Goebel et al., 2010). Ao longo das margens das geleiras da Sibéria, parece ter havido movimento leste-oeste, uma possibilidade devida ao fato de que as populações humanas contavam com a migração de rebanhos de renas e outros animais de grande porte. Theodore Shurr (2015) cita evidências genéticas para expansão populacional partindo da região de Altai-Sayan em direção ao leste, para a Beringia, por volta de 25.000 anos atrás, expansão essa portadora de marcadores genéticos tais que aparecem nas populações ameríndias posteriores. Esses migrantes do centro-oeste da Sibéria contribuíram com um marcador distinto do cromossomo Y M242, que havia divergido pelo menos 20.000 anos antes, em algum ponto da rota costeira do sul da Ásia. Outros migrantes equipados com microlâminas se deslocaram para o norte do Japão através da região da Península de Kamchatka, e levavam consigo M13O, marcador genético trazido do

Chifre de África através do Portão das Lágrimas, ao longo da costa meridional da Ásia e até a costa leste. Reunidos na região de Kamchatka, no noroeste da Sibéria, esses marcadores se tornaram os componentes genéticos distintivos dos migrantes para as Américas.

O interesse popular na origem dos canadenses das Primeiras Nações, dos nativos americanos e dos precursores arcaicos das civilizações da América Central remonta a artigo publicado na *National Geographic* por Thomas Canby, *The Search for the First Americans* (setembro de 1979), que narra o ano vivido pelo autor ao lado de arqueólogos pesquisando e escavando sítios nas Américas do Norte e do Sul. Bem articulado no seu tratamento do problema da migração, cauteloso com as datas oferecidas, informativo sobre o desenvolvimento da agricultura no México, e bem ilustrado, o artigo forneceu uma visão geral de conhecimentos então atuais, mas ainda aceitáveis hoje.

A Península de Kamchatka marcava o início de uma região extensa que se estendia do nordeste da Sibéria ao Alasca, incluindo o fundo do mar então exposto, estendendo-se para o norte no Oceano Ártico e para o sul em direção ao Pacífico, até as Ilhas Aleutas. Ela existiu porque vasto volume de água (70 milhões de metros cúbicos) estava contido no gelo continental durante o Último Máximo Glacial, de modo que o nível do mar se encontrava de 100 a 120 metros (320 a 400 pés) mais baixo do que hoje. Normalmente referido como uma "ponte terrestre" entre o Alasca e a Ásia, esta região é agora chamada de Beríngia (Figura 8), nome dado pelo geógrafo sueco Eric Hulten (1937). Essa região ecologicamente unificada se estendia por 1.609 km a oeste e 965 km de norte a sul, aproximadamente - ao todo, a 1605 km^2, maior que a área combinada dos estados do Texas, Novo México, Arizona e Nevada. Essa vasta região era o vestíbulo através do qual os viajantes asiáticos chegavam às Américas.

Dado o quão recentemente entendemos os movimentos demográficos nos tempos pré-históricos, é uma surpresa que a primeira especulação sobre migração humana vinda da Ásia tenha sido publicada em 1797 por Thomas Jefferson (1954: 100-101): "Surgiu uma grande pergunta: de onde vieram aqueles habitantes aborígines da América? (...) As descobertas tardias do Capitão Cook, costeando de Kamchatka até a Califórnia, provaram que, se os continentes da Ásia e América são separados, é apenas por uma faixa estreita. De modo que de lá os habitantes podem ter passado para a América". Jefferson sugeriu essa hipótese em decorrência da "semelhança entre os índios da América e os habitantes da Ásia". A evidência que temos hoje é uma versão da observação casual de Jefferson: a semelhança de genes entre os índios da América e os habitantes da Ásia. A história é mais complexa, é claro, mas Jefferson não deve ser descartado como simplesmente aquele que arriscou um palpite.

As evidências - não apenas um kit de ferramentas que incluía agulhas de costura e tecnologia de microlâminas, mas também marcadores genéticos rastreáveis – sugerem que há 30.000 anos alguns grupos chegaram à Beríngia. As evidências da presença do *H. sapiens* na América do Norte e do Sul fornecem uma data consideravelmente posterior, em torno de 14.000 anos atrás. Esse intervalo de tempo estimado de 16.000 anos permaneceu um mistério antropológico por várias décadas, até que se percebeu que Beríngia era um ecossistema habitável durante esse período em que a glaciação bloqueou o movimento além do Alasca. Os recursos animais incluíam o bisão, a rena, cavalos, leões, mamutes, bois-almiscarados, saigas e rinocerontes-lanudos, juntamente com uma variedade de mamíferos marinhos (Brigham-Grette et al., 2004). Durante todo esse período, toda a Beríngia, exceto a costa sudeste, ficou livre de gelo glacial. Era rica em recursos florais e de fauna, tendo as margens oceânicas uma fonte confiável e usual de recursos alimentares. A ideia de que a Beríngia serviu de refúgio habitável para humanos por um período prolongado foi sugerida pela primeira vez por Hulten (1937), um botânico e geógrafo, que explorou a região e publicou extensivamente sobre a rica flora da região de Yukon até a Sibéria, mas sua sugestão permaneceu por décadas pouco mais do que uma especulação interessante.

A maioria das discussões iniciais sobre migração humana foram especulativas e permaneceram assim até que surgiram evidências científicas. A família de idiomas esquimó-aleútes, que varia do Alasca ao norte do Canadá, está relacionada com os ramos mais orientais da família euro-asiática (Ruhlen, 1994: 169-170), mais notavelmente o Yupik-siberiano falado pelo povo Yupik na península de Chukotka, no nordeste da Rússia, embora as semelhanças linguísticas entre as línguas norte-americanas e asiáticas forneçam evidências ligeiras. As semelhanças entre a mitologia do norte da Ásia e as lendas das tribos inuítes, esquimós e Primeiras Nações do Canadá sugerem continuidades entre a Ásia e a América do Norte que indicam o que foi chamado de cultura circumpolar, mas essas semelhanças não têm o rigor de evidências científicas. Hoje, a genética se tornou o árbitro definitivo.

No início dos estudos genéticos, Torroni et al (1993) isolaram quatro haplogrupos de mtDNA fundadores, exclusivos de habitantes arcaicos das Américas, identificando-os como A, B, C e D, e que se tornaram as primeiras quatro letras do alfabeto filogenético. A teoria de uma "parada beringiana", apresentada por Tamm et al (2007), baseada no inventário de Hulten acerca um ecossistema floral de suporte, também é conhecida como Modelo de Incubação Beringiana, um termo que define o que aconteceu em termos genéticos. Durante um período de aproximadamente 16.000 anos, quatro mutações únicas foram incubadas por cerca de 700 a 900 gerações de beringianos. Eventualmente, A, B, C e D foram transportados para o sul como os quatro marcadores definitivos do haplogrupo de mtDNA da população fundadora das Américas.

Povoando as Américas

Enquanto o Canadá permanecia fora de alcance em função das geleiras, a migração de humanos arcaicos provindos da Beríngia era impossível: uma caminhada de 300 quilômetros do *H. sapiens* pré-histórico através de geleiras, centenas de metros acima do nível do mar, sem acesso imediato a uma fonte de alimento, estava além da possibilidade. A migração para o sul teve que aguardar o recuo dessas geleiras. Na década de 1950, os glaciologistas teorizaram que o derretimento do gelo teria levado à separação das geleiras Laurentide e Cordillera, resultando em um "corredor sem gelo" ao longo da borda leste das Montanhas Rochosas, na atual província canadense de Alberta. Levando a Montana, a hipótese de uma migração por esse corredor ganhou popularidade imediata por várias décadas, parcialmente porque levaria ao interior continental e, portanto, era algo que se adequava à teoria predominante de que a primeira cultura nativa americana foi a cultura de Clóvis, a assim chamada tradição de ferramentas própria da região de Clóvis, no Novo México.

O destaque de que esse "corredor sem gelo" desfrutava na imaginação é bem ilustrado no livro de Dan Cushman, *The Great North Trail* (1966). É um excelente documento de época, rico em detalhes que ligam a rota do Alasca à Montana, a "Trilha de Todas as Eras", a várias outras trilhas do norte – por exemplo, as trilhas de gado – seguindo para o norte do Texas. Ao conectar as várias trilhas históricas à rota de migração original para as Américas o autor revela sua predileção por uma visão ampla e criativa da história; ele poderia ser considerado um *big historian* primitivo. Isso é particularmente evidente em seu capítulo, "A trilha do cavalo de três dedos", em que explora a pré-história dos cavalos, ou mesmo de uma vasta megafauna antiga. Mas em relação ao seu tratamento da rota do Alasca para Montana, era muito cedo para obter informações factualmente precisas ou um relato plausível da entrada de humanos na América do Norte.

Pondo de lado a "Trilha de Todas as Eras" de Cushman - seu subtítulo romantizado –, através das regiões glaciais do Canadá, o fato era que essa rota não estaria disponível até algum tempo após o derretimento glacial ocorrido por volta de 16.000 anos atrás; um corredor navegável não teria sido exposto até cerca de 13.000 anos atrás. Embora os geólogos tenham verificado a plausibilidade desse corredor sem gelo, sua praticidade foi questionada pelo antropólogo Knut Fladmark (1979); qualquer corredor como esse teria de passar entre penhascos de gelo com 1km de altura. Thomas Canby (1979) sugeriu que um lugar assim seria um "local formidável (...) um vale com paredes de gelo e ventos frios, neves ferozes e nevoeiros arraigados". Brian Fagan (1987: 140) acrescentou que era "na melhor das hipóteses, uma das paisagens mais áridas e empobrecidas que os seres humanos poderiam possivelmente explorar".

Enquanto Dan Cushman imaginou que essa rota era possível, ela era na verdade delimitada por penhascos perigosos, ameaçada por quedas repentinas de gelo, inundada por séculos de derretimento das paredes glaciais, por lagos gelados e um ambiente em constante mudança, o que atrasaria o desenvolvimento de um ecossistema de suporte. Um estudo de DNA antigo ao longo desta rota liderada por Eske Willerslev elaborou uma narrativa evolutiva nesse corredor, mostrando que a falta de recursos florais, madeira para combustível e ferramentas, e animais de caça, tornariam o corredor "biologicamente inviável" antes de 12.600 anos atrás (Wilken, 2016). Além disso, nenhum traço de movimento humano ao longo da rota de 1500 km entre o Alasca e Montana foi descoberto.

Mais de meio século atrás, Wilson Duff (1964: 7) arriscou uma hipótese de que "a história indígena da Colúmbia Britânica (...) começou pelo menos cem séculos antes do nascimento da própria província". Sua estimativa acabou sendo uma subestimação considerável. Crítico da teoria do corredor sem gelo, Fladmark (1979) defendeu uma rota costeira pelo Pacífico, que agora é reconhecida como a mais provável por várias razões. O primeiro efeito do derretimento glacial foi um recuo da geleira Cordillera costeira, que expôs as praias do sul do Alasca e a margem continental da Colúmbia Britânica. O estabelecimento de um ecossistema floral costeiro e a entrada de fauna prosseguiriam por séculos, talvez décadas. De acordo com Carol Mandryck et al (2001), "dados paleoecológicos sugerem que a paisagem costeira estava em parte vegetada e provavelmente capaz de sustentar uma fauna terrestre, incluindo seres humanos". Lesnek et al (2018) sugeriram uma cronologia precisa: "Análises paleogenéticas recentes sugerem que a colonização inicial da Beríngia ocorreu já em 16 mil anos atrás, através de um corredor degelado ao longo da costa do Pacífico Norte (...) produtivos ecossistemas marinhos e terrestres foram estabelecidos quase imediatamente (...) um caminho aberto e ecologicamente viável através do sudeste do Alasca estava disponível a partir de 17.000 anos atrás".

Enquanto a antiga costa do Pacífico está hoje submersa em até 100 metros abaixo do nível do mar, a plataforma continental exposta se estende para o oeste dos perigosos recifes e rochas da costa. Especulações iniciais de que seriam necessárias embarcações baseavam-se imaginativamente no diagnóstico de que seria necessário contornar a perigosa costa de falésias, rochas marinhas e o quebra-mar na margem continental até o sul de Oregon e norte da Califórnia, mas isso foi descartado como algo provavelmente além das habilidades de construção dos beringianos arcaicos – pelo menos nesse momento inicial. As evidências sugerem que uma rota costeira acessível teria sido viável assim que o derretimento começara, talvez mesmo antes disso. A costa mais externa, geralmente correspondendo às margens ocidentais das ilhas marinhas de hoje - Prince Edward, Haida Gwaii e Vancouver – não tinha gelo e, portanto, era um habitat adequado para os recursos florais e de fauna. Heaton (1996), por exemplo, mostrou que a ilha Prince Edward, na costa sudeste do Alasca, foi um refúgio para o urso castanho durante um período de 40.000 anos, uma demonstração de sua aptidão para abrigar uma ampla variedade de espécies mamíferas, incluindo a humana.

Uma evidência decisiva é a presença de índios arcaicos em alguns locais nas Américas muito antes de o corredor sem gelo ser ecologicamente viável. Uma análise de vestígios de coprólitos fósseis das cavernas de Paisley lideradas por Eske Willerslev (Gilbert, 2008) indica uma presença humana no Oregon por volta de 14.000 anos atrás, catorze séculos antes do corredor sem gelo ser capaz de permitir a presença humana. Ainda mais surpreendente é a evidência do sítio de Monte Verde, no Chile, que mostra que os humanos modernos o alcançaram por volta de 14.000 anos atrás, uma datação que indica uma dispersão surpreendentemente rápida dos primeiros seres humanos nas Américas. Além disso, é quase impossível imaginar humanos arcaicos viajando pelo interior por toda a extensão das Américas tão rapidamente; a presença de muitos ambientes habitáveis ao longo do caminho teria simplesmente contido esse avanço. Por outro lado, é provável que a migração litoral tivesse levado os migrantes adiante. Por apenas dez milhas de deslocamento por ano - pouco mais que uma semana de lazer - levariam os primeiros migrantes por toda a extensão das Américas em um único milênio.

Caminhando pela Costa

Tendo em mente a diferença de comportamento habitual entre colonos e aventureiros, esperaríamos um rastro de evidências de assentamentos confirmando a passagem sul, deixado para trás por aventureiros que não teriam hesitado em seguir em frente. Os descendentes posteriores desses colonos deixaram uma trilha genética que pode ser encontrada em vestígios fósseis. Um espectro surpreendente de evidências emerge de praticamente todas as descobertas. Escavações na caverna On Your Knees, na ilha Prince of Wales, no sudeste do Alasca, renderam um conjunto de ferramentas bifaciais e de microlâminas, além de mais de restos ósseos de 12.000 anos de idade – chamados de “Shuka Kaa” (“Homem à nossa frente”) pela tribo Tlingit da região. Um marcador genético (especificamente o subhaplogrupo do mtDNA D4h3) mostra que ele está relacionado às tribos da Colúmbia Britânica ao sul – não apenas aos Tlingit, mas também aos Haida, Nisga e Tsimshian e, também aos grupos centro e sul-americanos vivendo a milhares de quilômetros ao sul, Karitiana, Suruí e o Ticuna da Amazônia brasileira (Kemp et al., 2007; Bellwood, 2013: 89). Aqui, um único esqueleto, combinado à coleção genética formada ao longo de milhares de quilômetros de costa, estabelece uma antiga trilha de migração. Na verdade, é isso que encontramos em toda a costa do Pacífico.

Figure 7. The West Coast Route into the Americas has emerged as the most viable way past glaciers during the last Ice Age when shorelines were seaward of present locations. Paleoindian sites on the coast and in the interior indicate rapid dispersal across the continent. Note that the ice-free corridor, once illustrated on virtually every migration map, has here been eclipsed by definitive evidence for the coastal route. Image source: www.TranspacificProject.com

Mais ao sul, o arquipélago de Haida Gwaii (anteriormente as Ilhas Queen Charlotte), localizado a 45 a 60 km da costa continental, juntou-se a essa costa durante o Máximo Glacial; hoje é o território da nação Haida. Várias cavernas – K1, Gaadu Din 1 e 2 – abrigaram ferramentas de pedra de aproximadamente 10.000 anos, evidência de ancestrais dos Haida que se acredita terem ocupado Haida Gwaii desde pelo menos 13.000 anos atrás, com evidência de descendência, a partir de DNA mitocondrial e do cromossomo Y, dos antigos habitantes da Beringia. Dada a possível migração a partir da Beringia já em 16.000 anos atrás, é possível que evidências adicionais estejam aguardando serem descobertas.

O acesso a frutos do mar é uma constante ao longo da costa do Pacífico. O acesso à água doce é igualmente confiável. Em intervalos de poucos quilômetros, riachos jorram das montanhas costeiras, algumas ainda alimentadas por geleiras, muitas outras pela umidade e chuvas do Pacífico, à medida que os ventos marítimos avançam sobre a faixa costeira. Inúmeros fiordes forneceram acesso a alimentos fluviais e marítimos. As tribos atuais da Colúmbia Britânica Tsimshiam, Gitxsan, Haisla e Wuikinuxv ocupam antigos territórios interioranos ribeirinhos colonizados por migrantes. No estado de Washington, os Makah, Quileute, Hoh e os Salish da Costa são colonos permanentes, onde córregos e rios fluem para fora das florestas úmidas das Montanhas Olímpicas. A atratividade dos locais ribeirinhos interioranos é evidente com a tribo Walapa que se estabeleceu ao longo dos rios Chehalis e Walapa. A tribo Chinook assentou-se na foz do rio Colúmbia e avançou por ele por mais de 160 km até as Cataratas Celilo.

Considerar cuidadosamente a costa do Pacífico como uma rota primária para o povoamento das Américas é algo que se deve ao fato de que locais como Haida Gwaii e os fiordes terem sido inacessíveis em qualquer direção exceto para o norte. A Colúmbia Britânica está repleta de montanhas em todas as direções, desde o litoral a leste até as Montanhas Rochosas. São jovens montanhas em termos geológicos – irregulares e ameaçadoras – surgidas de colisões e da subducção da placa do Pacífico durante a complexa constituição orográfica do oeste da América do Norte. Hoje quase inacessível do interior, exceto por rodovias para Prince Rupert e Vancouver, toda a costa foi isolada de migrações vindas dele, certamente de grupos - se tiverem existido - que podem ter viajado até Montana antes de sair do corredor livre de gelo. Os três grupos que dominam a ilha de Vancouver, a maior da costa oeste das Américas, têm conexões genéticas com populações costeiras ao norte e ao sul; marcadores genéticos interiores são derivados. Rica em recursos florais, faunísticos e marinhos com correntes marítimas quentes, a Ilha de Vancouver é o lar de três grupos que se tornaram bem conhecidos. Os Kwakiutl ganharam destaque com o romance de Margaret Craven, *I Heard the Owl Call My Name* (1967), que fez parte da lista de best-sellers do *New York Times* tão logo publicado por uma editora americana. Os Nuu Chah Nulth são conhecidos através das aventuras de John R. Jewett (1783-1821), que sobreviveu a um cativeiro de 28 meses sob o poder desse grupo, e escreveu um livro de memórias de grande interesse antropológico – *Suffering of John R. Jewett* (1815). Os Salish da Costa ocuparam regiões litorâneas da ilha de Vancouver com uma presença proeminente no noroeste americano. Os locais de habitação, do sudeste do Alasca ao estado de Washington, são mais claramente entendidos como sítios relictos que marcam a trilha das migrações beringianas para o sul ao longo da costa.

Recentemente, Duncan McLaren et al (2018) descobriram 29 pegadas humanas arcaicas de vários tamanhos na costa da Ilha Calvert, Colúmbia Britânica, datando de 13.000 anos atrás. Na ilha de Santa Rosa, a 30 quilômetros da costa de Santa Bárbara, foram identificados cerca de vinte locais de ocupação humana, datados de 12.000 a 11.000 anos atrás. As evidências incluem locais de fabricação de ferramentas, pontas líticas e depósitos substanciais de conchas de abalone (Rick et al., 2013). Evidências genéticas e arqueológicas convergem para estabelecer a Rota da Costa Oeste como a principal rota de migração para as Américas.

Como sugerido anteriormente, a reconstrução bem-sucedida das rotas pioneiras de migração é possível devido a elementos permanentes no comportamento humano. Alguns migrantes estão preparados para se estabelecer em um novo local, se as condições ambientais de clima, comida, e água são favoráveis. É possível que isso valha para a maioria e para os mais velhos membros dos grupos migrantes. A estabilidade e a confiabilidade regional dos recursos alimentares podem ter incentivado a expansão para norte e sul através da costa, e talvez para o interior ao longo de uma via navegável, onde a coleta de recursos ribeirinhos teria contribuído para a dieta. O resultado pode ter sido uma comunidade relicta expansiva. Séculos ou milênios depois, essas comunidades relictas preservam marcadores genéticos, tornando essas comunidades marcos ao longo da rota de migração original. Enquanto isso, aventureiros e exploradores mostram inquietação, optam pela independência e seguem em frente. Previsivelmente, serão esses os membros mais jovens do grupo. Eles carregam os marcadores genéticos de seus antepassados, mas com o tempo surgem novos marcadores que estendem a direção geral da migração.

Figure 8. A proliferation of late Pleistocene sites west of the Andes marks the primary coastal migration route. The following sites are referred to in the text: 6. Las Vegas; 30. Mylodon Cave, Cueva del Medio; 36. Monte Verde. Map source: Dillehay 1999.

Entre os migrantes ao longo da rota costeira primária para as Américas, seria de se esperar mais colonos do que aventureiros e, portanto, uma densidade considerável de assentamentos, e, de fato, esse é o caso. As tribos das primeiras nações costeiras da Colúmbia Britânica e as tribos dos índios americanos de Washington e Oregon somam mais de cinquenta; outras cinquenta ocuparam a Califórnia, com subgrupos somando outras quarenta. Inúmeras rotas de dispersão para o interior estavam disponíveis: o rio Fraser, na Colúmbia Britânica, os rios Skagit e Colúmbia, em Washington, os rios Umpqua e Rogue, no Oregon, os rios Klamath e Salinas, na Califórnia, e o rio Colorado, no México. Embora todos apresentassem locais adequados para o assentamento, os colonos que seguiram essas rotas interiores eram minoria. Ainda hoje, a costa oeste tanto do Canadá quanto dos Estados Unidos têm a maior densidade de população indígena, com um terço dos nativos americanos vivendo na Califórnia. Isso reflete sua entrada na costa oeste das Américas, da mesma forma que a chegada de europeus na costa atlântica se reflete em sua maior densidade ao longo da costa leste.

Rota Costeira da América Central e do Sul

As imensas massas terrestres da América do Norte e do Sul levaram ao México e, em particular, à América Central, consideradas principalmente como uma ponte terrestre, principalmente onde alcança uma largura de 50 quilômetros no Istmo do Panamá. Certamente, um inventário de sítios pré-históricos na América do Sul indica que vários grupos passaram através dessa ponte e foram muito além da América Central. Embora a

Figure 9. Patagonia, the final stop on the great migration, is a hostile environment of numerous islands, ragged mountains, inland waterways, and rich marine resources that have served *Homo sapiens* migrants for thousands of years.

Image source: www.patagonia.com.

maioria das evidências de assentamento costeiro ainda espere por ser descoberta – ou esteja muito abaixo do nível do mar – a América Central ofereceu adequados ambientes interioranos para assentamentos que eventualmente de desenvolveram em civilizações avançadas, mantidas pelo cultivo irrigado de milho, feijão, abóbora, tomates, pimentões e amaranto. Os toltecas desenvolveram agricultura aprimorada com barragens e canais de água ao longo dos vales dos rios da Costa do Golfo. Os astecas, posteriores, que ganharam o controle do Golfo do México até o Pacífico, desenvolveram a agricultura usando o sistema de chinampas, composto de canteiros suspensos e canais de água elevados. Os maias desenvolveram uma agricultura semelhante em canteiros, juntamente com o cultivo na península de Yucatán. A civilização tolteca foi baseada em séculos, talvez milênios, de assentamentos permanentes, de modo que eles desenvolveram uma tradição avançada de escultura; os astecas e os maias construíram civilizações monumentais de pedra extraída com considerável complexidade social e organização política, que faz lembrar as culturas do Velho Mundo dos Vales do Nilo, Tigre-Eufrates e Rio Indo.

Enquanto essas civilizações da América Central se desenvolveram em uma base agrícola, muitos migrantes iniciais se mudaram para o continente sul. Em um levantamento acerca do final do Pleistoceno na América do Sul, Tom Dillehay (1999, Fig. 1) mapeou 41 sítios, mais de 20 deles a oeste dos Andes, ao longo da rota costeira do Pacífico, da Colômbia à Patagônia.

O litoral do Peru pode eventualmente apresentar evidências de passagens e assentamentos arcaicos de migrantes, embora dezenas de locais bem desenvolvidos nos Andes peruanos testemunhem o clima adequado e os recursos de suporte que resultaram em assentamentos estáveis com duração de séculos ou milênios. Na costa do Equador, um conjunto de sítios revelou a centralidade do uso de recursos alimentares marinhos, incluindo a zona das marés e as águas dos manguezais dos estuários. Cerca de 32 sítios arcaicos foram identificados na Península de Santa Elena, conhecidos coletivamente como o sítio de Las Vegas. O sítio 80, a 3 km da costa, é caracterizado por um depósito feito durante 4.000 anos, cujo nível mais inferior foi datado de 10.400 anos (Stothert, 1988). No entanto, os acampamentos à beira-mar e os concheiros indicam ocupação de curto prazo ou ocasional, e dependência de alimentos vegetais e animais terrestres, mas também de recursos marinhos, inventariados na forma de 25 variedades de peixes, 1 de crustáceo e 15 de moluscos. Stothert (2011: 373) estima que os ocupantes do sítio 90 de Las Vegas se fiaram no consumo de recursos marinhos e fluviais na proporção de metade dos alimentos que consumiam. As espécies consumidas eram quase todas de águas rasas, sugerindo pesca realizada durante deslocamentos diários pelo leito, e não trabalho de coleta de peixes com uso de embarcações. A predominância de conchas de moluscos de manguezais (57-80%) pode indicar a conveniência da prática da coleta em águas próximas aos manguezais. Na falta de evidências, a coleta em águas rasas provavelmente caracterizou a colheita marinha em toda a migração costeira para fora da África. A ocupação prolongada fornece evidências que se aplicam a todos os assentamentos costeiros relictos: a confiabilidade dos recursos marinhos é responsável pela primazia do forrageamento nas praias e dos assentamentos costeiros, que caracterizavam a vida pré-histórica.

Em 1975, o antropólogo Tom Dillehay descobriu um local ao ar livre no Chile, em um afluente fluvial em Monte Verde, a 58 km da costa do Pacífico. A importância para a cronologia da migração em direção ao Novo Mundo, e a riqueza de artefatos recuperados neste sítio foram discutidas em detalhes (Fagan 1987: 174-175; Dillehay, 1999, 2000; Bellwood, 2013). Preservado por um pântano turfoso, o sítio produziu ossos, carvão, roupas de couro, restos de estacas de uma dúzia de cabanas e um pedaço de carne do qual o DNA pôde ser extraído. O sítio, datado de 14.800 anos atrás parece ter sido ocupado por um grupo típico de forrageamento de cerca de 30 indivíduos, com evidências de uma dieta mista vegetal, animal e marinha. Como observado anteriormente, a datação de Monte Verde, que antecede um corredor viável sem gelo pelo Canadá por muitos séculos, fornece confirmação primária de uma migração costeira em vez de interiorana, embora a chegada antecipada a Monte Verde forneça um cenário surpreendente de 16.000 km de povoamento rápido da América do Sul. Nesse sentido, Peter Bellwood (2013: 91) sugere que uma população migrante poderia ter "percorrido o longo extremo oeste das Américas em apenas dois curtos milênios entre 16.000 e 14.000 anos atrás (...). Algumas centenas de pioneiros dobrando sua população a cada 50 ou 100 anos ou mais teriam tido pouca dificuldade em percorrer essa distância muito rapidamente, mantendo contato com outros grupos deixados para trás". Monte Verde é, de fato, o mais antigo sítio confirmado nas Américas. Uma relativa falta de ferramentas de pedra indica que esse grupo não dependia da caça, sendo formado principalmente por coletores de recursos vegetais e marinhos – sem dúvida um legado de milênios de jornada pelo litoral oceânico.

O braço final desta odisseia humana se deu quando os humanos chegaram à Patagônia, a extremidade sul da América do Sul. A caverna de Milodon ("Cueva del Milodon"), agora um Monumento Nacional, recebeu este nome devido à presença de vestígios de milodontes pré-históricos (preguiças-gigantes, N.T) extintos a mais de 10.000 anos atrás. Pedras rachadas pelo fogo e ferramentas líticas foram recuperadas na caverna junto com restos humanos. Fora da rota da costa oeste, mas localizada no rio Pinturas da Argentina, a Caverna das Mãos ("Cueva de Las Manos") mostra evidências de ocupação já em 13.000 anos atrás. Os vestígios artísticos que lhe dão nome apresentam várias mãos estampadas, e foram datados a partir dos tubos de osso usados para pulverizar a tinta em 9300 anos atrás. Imagens semelhantes de mãos, quase sempre a mão esquerda, são bem conhecidas da arte neolítica das cavernas na França.

A costa do Chile, de cerca de 4000 km, que inclui a Patagônia e o arquipélago da Terra do Fogo, é um dos litorais mais hostis do mundo. São 4.872 ilhas, poucas delas habitadas, e a maioria inóspita.

A região é rica em frutos do mar ao longo de centenas de quilômetros de vias navegáveis interiores. Spa Piana e Orquera (2009) sugeriram que os colonos da Patagônia e da Terra do Fogo "tornaram-se intensamente dependentes dos recursos costeiros e marinhos e projetaram meios tecnológicos especiais para sua aquisição e processamento, incluindo a navegação". Dada a extensão das ilhas e hidrovias na extremidade da América do Sul e as temperaturas quase congelantes das águas oceânicas, é provável que os migrantes para a Patagônia tenham sido impelidos a desenvolver embarcações logo no início , talvez dentro de um ou dois séculos após a sua chegada.

Ao avaliar o início dos assentamentos na América do Sul, Tom Dillehay (1999: 206-207) escreve: "Sendo o último continente ocupado por seres humanos, mas um dos primeiros locais em que a domesticação ocorreu, a América do Sul oferece um importante caso a respeito de rápidas mudanças culturais e adaptação regional". Entre vários "gatilhos" para a mudança e adaptação, Dillehay aponta para o ambiente costeiro, particularmente o "estilo de vida do *H. sapiens* em constante mudança, resultante de ter percorrido toda a extensão do Hemisfério Ocidental". Seu foco no ambiente costeiro pode muito bem aplicar-se a toda a migração pela margem oceânica, com seus recursos marinhos permanentemente confiáveis, que levaram seres humanos da África do Sul à Patagônia, uma jornada que se desenrolou ao longo de mais de 60.000 anos. A *National Geographic* (março de 2006) chamou-a de "a maior jornada já contada".

Migração ribeirinha interior

Reunir diversas descobertas e escavações de todo o mundo nos permite construir uma rota primária para o povoamento do mundo. Organizados cronologicamente em uma narrativa contínua, migrações secundárias entram em foco. Em adição a uma fonte de alimento constante e confiável a partir de recursos marinhos, os humanos precisaram de acesso diário a água doce. Isso faz dos riachos e da foz dos rios ao longo da costa oceânica os pontos de parada necessários para os migrantes costeiros. Entre a África do Sul e a Patagônia, esse número chega às centenas. Oferecendo recursos ribeirinhos de água doce, a maioria dos córregos que fluem das terras altas do interior convidaria a migração a montante. Em alguns casos, essas migrações ribeirinhas alcançariam ambientes agradáveis, longe de tempestades e ventos oceânicos.

Com isso em mente, podemos apontar para assentamentos fluviais no interior dos quais podemos inferir migrações pré-históricas de forrageamento. O vale do Tigre-Eufrates fornece a primeira rota de separação por dispersão da principal rota costeira. A Mesopotâmia e as colinas circundantes são as mais escavadas no mundo; são centenas de vestígios de assentamentos pré-históricos e locais de trabalho nas montanhas vizinhas de Zagros, sugerindo longa ocupação e crescimento populacional. Charles Keith Maisels (1990: 124) estima que a região eventualmente abrigou de 2000 a 4000 grupos de 50 a 100 membros. As cidades surgidas posteriormente na Mesopotâmia - Ur, Eridu, Nippur, Kish, Babilônia e Mari - podem ter sido erguidas sobre locais de assentamento pioneiro, porém não mais acessíveis. Além disso, a rota do Tigre-Eufrates para o norte forneceu um corredor de migração que, com pequenas mudanças direcionais, ruma para noroeste em direção a Anatólia (Turquia), o portão de entrada para a Europa, e diretamente ao norte em direção ao interior da Ásia. Em algum lugar ao leste do Chifre da África, os haplogrupos N (mtDNA) e R (Y DNA) divergiram a partir do haplogrupo M, provavelmente já em 80.000 anos atrás. Torroni et al (2006) argumentam que M, N e R ocorreram entre a África Oriental e o Golfo Pérsico; a presença de N e R em toda a região da Eurásia ao norte sugere que as rotas ribeirinhas para o norte no Tigre e no Eufrates podem muito bem ser uma rota secundária de grande importância no povoamento do norte.

Mais a leste, na rota costeira pelo sul da Ásia, o rio Indo atraiu migrantes para as terras altas do Paquistão, onde, muito mais tarde, foram estabelecidas dezenas de sítios ribeirinhos que eventualmente evoluíram para uma imensa civilização. Os locais das cidades agora em ruínas de Harappa e Mohenjo Daro provavelmente foram ocupados por alguns dos primeiros migrantes ribeirinhos, longe das margens do oceano. Na costa oeste da Índia, os rios Narmada e Tapi forneciam rotas para o interior da Índia, mas a maioria dos rios peninsulares indianos surgiu no oeste e correu para o leste até a Baía de Bengala - entre eles Krishna e Godivari com seus numerosos afluentes, e os rios Brahmani e Mahanadi. A ancestral de todas as rotas fluviais para o interior seguiu o Ganges e seus numerosos afluentes, que formam uma vasta bacia fértil alimentada pelas geleiras do Himalaia. É a segunda maior bacia hidrográfica do planeta, drenando 1.086.000 km2, incluindo partes de Bangladesh, Nepal e Paquistão. A riqueza ambiental do subcontinente indiano, incluindo recursos alimentares ribeirinhos, sem dúvida atraiu numerosos assentamentos ao interior nos tempos pré-históricos e, eventualmente, uma das culturas mais ricas do planeta; ali nasceram o hinduísmo e o budismo.

Mais ao leste, o rio Irawaddy, em Mianmar, fornecia uma rota semelhante no sopé do Himalaia, com locais ocupados há muito tempo, evoluindo para os sítios posteriores de Yangon (Rangoon), Paya (Prome), Bagan e Mandalay. O rico ambiente e as estruturas monumentais de Angkor, que cobrem 400 quilômetros quadrados às margens de um afluente do rio Mekong, sugerem que elas podem ter se desenvolvido sobre sítios arcaicos de migrantes ribeirinhos no Camboja milênios antes. Na China, o Huang Ho (rio Amarelo), que se estende por 5.464 km continente adentro, foi um local de assentamentos pré-históricos a partir dos quais a civilização chinesa surgiu. Densamente povoados e devastados por numerosos eventos de inundação, é provável que os sítios mais arcaicos tenham sido carregados pelas águas, embora qualquer uma das dez maiores cidades do Huang Ho possa estar localizada onde o *H. sapiens* pré-civilizado se estabeleceu. Ao sul, o rio Yangtse, com vários afluentes, o rio mais longo da Ásia, flui por 6.380 km, passando por dezenas de locais ribeirinhos, incluindo Nanying e Xangai, antes de desembocar no Pacífico. Enquanto alguns migrantes chegaram à China a partir do interior ocidental, esses rios do Leste Asiático forneceram as rotas mais acessíveis, confiáveis e provavelmente as primeiras para o interior a partir da rota costeira principal.

Na América do Norte, o Rio Fraser, que se estende 1.375 km, forneceu uma rota para os vales do interior da Colúmbia Britânica. Seguindo a borda do estado de Washington com o estado de Oregon, o rio Colúmbia, e também os afluentes dos rios Okanagan, Bitterroot e Snake, proveram 2.000 km de rota fluvial para as Montanhas Rochosas do Canadá e dos Estados Unidos. As Primeiras Nações e os sítios de nativos americanos nas regiões interioranas do noroeste do Pacífico refletem as migrações fluviais de migrantes arcaicos. Desaguando na Baía de São Francisco, os rios Sacramento e San Joachin, com dezenas de afluentes partindo das montanhas Sierra, forneceram rotas de migração ribeirinha para a maior parte do interior da Califórnia. O rio Colorado e o rio Green proporcionavam acesso semelhante ao Arizona e a Utah, regiões a leste do Novo México e Colorado, e para o norte em direção a Wyoming. A eficácia dessa rota é clara, por exemplo, na descoberta dos *kiva* dos nativos americanos ao longo rio Colorado nas profundezas do Grand Canyon (Harvey, 2008) - uma estrutura familiar se comparada às rebuscadas ruínas dos Anasazi no Chaco Canyon.

A partir da rota costeira primária, as rotas ribeirinhas forneciam acesso à maior parte do sul da Ásia, leste da Ásia e América do Norte e do Sul. A configuração geográfica da Europa, no entanto, forneceu um cenário diferente. Com exceção dos rios que correm para o Mar Negro - o Dnieper e o Danúbio - que poderiam levar migrantes para o interior da Europa, a migração fluvial ao longo de cursos de água que correm para o oeste em direção ao Oceano Atlântico - o Loire, o Sena, o Reno, o Elba e Vístula - levaram migrantes a jusante vindos de locais interioranos.

A maior aventura

Por volta da ocasião em que os migrantes costeiros deixaram a África, já haviam acumulado cerca de 100.000 anos de experiência em coletar, caçar e sobreviver com recursos marinhos nas margens sul e leste do continente. A rápida dispersão pelo sul e pelo leste da Ásia adicionou experiência coletiva com uma variedade de ambientes ribeirinhos e lacustres ao longo de, talvez, outros 50.000 anos. Nos arquipélagos costeiros do sudeste e leste da Ásia, o *H. sapiens* foi motivado a desenvolver embarcações duráveis, um processo de tentativa e erro que pode ter ocorrido ao longo de milênios com exploração confinada às hidrovias das ilhas. Fosse essa navegação movida a vela ou a remo é algo que continua sendo uma questão de especulação, embora o uso de ambos os meios pelos fenícios, gregos e romanos durante aproximadamente a mesma época sugira métodos de navegação semelhantes ao longo das costas asiáticas. Sem dúvida, maneiras de coletar água da chuva combinadas com habilidades bem-sucedidas de captação de recursos marinhos permitiram longas aventuras ao longo da costa e entre centenas de ilhas. Em algum momento, essas aventuras se expandiram para a exploração do Oceano Pacífico.

Setenta anos atrás, Thor Heyerdahl popularizou a ideia de deriva oceânica, com ventos e correntes em sua expedição Kon-Tiki, mas sua premissa de que as ilhas do Pacífico foram povoadas por fluxos vindos da América do Sul não resistiu à análise genética dos ilhéus. No entanto, a deriva com correntes e ventos, sem dúvida, teve um papel na exploração oceânica do sudeste e leste da Ásia. K.R. Howe (2003) defendeu a ideia de que os primeiros exploradores remaram ou navegaram contra o vento, e o fizeram com alguma confiança de que poderiam retroceder com facilidade, apenas flutuando ou navegando a favor do vento. Por analogia com as habilidades perceptivas dos contemporâneos nativos de hoje, podemos assumir a navegação pelo Sol, Lua e estrelas como uma virtual certeza. A familiaridade com as mudanças sazonais no movimento das constelações, juntamente com as correntes marítimas prevalecentes, acabou levando à confiança, somada à ousadia e bravura inimaginável em mar aberto.

Por volta de 3500 a.C., aventureiros partiram em viagens marítimas que acabaram por levá-los a criar assentamentos nas Ilhas Bismarck e Salomão, a leste da Nova Guiné; depois, nos 4.000 anos seguintes, na Melanésia, Micronésia e Polinésia. Outros cenários postulam uma partida vinda das Filipinas. Sem dúvida, incursões em alto mar ocorreram com regularidade antes do início das maiores aventuras de exploração. No entanto, as enormes distâncias entre o continente e as Ilhas do Pacífico definem essa aventura como um ato supremo de risco, especialmente considerando as dimensões do maior oceano da Terra. As probabilidades de chegar à terra firme significaram que alguns aventureiros, talvez muitos, devem ter se perdido; por outro lado, habilidades de sobrevivência já estariam bem avançadas: a sobrevivência no oceano por várias semanas era possível, aumentando assim as chances de atingir a terra firme. Os números relativos às expedições são impossíveis de serem conhecidos; pode ter havido dezenas de partidas em diferentes gerações. Os retornos podem ter sido poucos; as perdas podem ser apenas especuladas. O que sabemos é que, ao longo de 3.000 anos, uma extensa variedade de ilhas do Pacífico foi bem povoada, ao longo de todo o caminho até a Ilha de Páscoa, a milhares de quilômetros de distância do continente asiático.

A análise genética tornou possível rastrear essas migrações nas ilhas do Pacífico. As semelhanças linguísticas fornecem a esperada confirmação. As continuidades culturais ilustram a dinâmica de migração por saltos de ilha em ilha, e de assentamento. Padrões rituais semelhantes fornecem um fio narrativo. A vida nas ilhas apresentou problemas nunca encontrados no continente, onde o aumento da população ou a depleção do solo poderiam ser contornados simplesmente deslocando-se para mais adiante. Tais problemas dentro dos limites confinados de ilhas forçaram uma adaptação que nem sempre foi bem-sucedida; o aparente colapso das condições de vida na Ilha de Páscoa e sua população em declínio fornecem o exemplo mais dramático, possivelmente ilustrando colapso ambiental ou social, ou ambos. Mas em algum momento entre os anos de 1.200 e 900 da Era Comum, os aventureiros que navegam para o norte da Polinésia Francesa avistaram ilhas no horizonte e talvez a fumaça ascendente da erupção do vulcão Kilauea, na Ilha Grande do arquipélago havaiano. Eles seguiram em frente, carregando consigo suas poderosas divindades lideradas pela deusa Pele, que adotou os vulcões havaianos como suas possessões enquanto os migrantes adotaram essas ilhas como suas. Ao puxarem suas embarcações para terra firme, concluíram um épico de 100.000 anos de povoamento da Terra. A maior jornada já feita chegou ao fim nas praias das ilhas mais isoladas do planeta.

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Mythopoetic imagination as a source of critique and reconstruction: alternative storylines about our place in cosmos

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Abstract
Temporal reflexivity requires that we recognize consciousness, society and history as mythopoetically constituted. Mythopoetic imagination can also be a means of critique of the prevailing myths. In complex pluralist societies, there are hegemonic struggles over constitutive myths, shaping both our explanatory accounts of the past and scenarios about possible futures. A widespread myth of contemporary liberal-capitalist societies comprises three temporal tiers: deep cosmic scepticism; various ethical and political lessons drawn from, and theories related to, this scepticism; and the capacity of technology and economic growth to bring us some comfort and enjoyment in our short lives. An alternative cosmic storyline centres on the prospects of life and culture, rather than death, and on our common evolvement also through collective learning. In this paper, I examine possible interpretations of the basic Big History (BH) narrative in view of these two ideal-typical storylines. How is BH positioned and positioning itself in relation to the main scientific myths of the 21st century? I assess the plausibility of BH in terms of both logos and mythos; and criticising BH's ambiguities, I argue in favour of the life-oriented storyline.

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Introduction

Big History (BH) is about developing a creation myth and origin story suitable to our globalized world characterised by (i) economic growth and ecological deterioration and (ii) by the existence of weapons of mass destruction and other risks. The idea is that this story must and can accord with modern science and its findings. The story must also be open to critique, revision and improvement. So far, the starting point has been that the Big Bang cosmology provides us with a scientific creation myth. The metatheory of emergence and complexity fills in the rest of the story.[1]

A difficulty is that modern science has been set against all myths. The standard modern meaning of myth has been that of a narrative that has no basis in reason and cannot be true. *Mythos* is opposed to *logos*. It is well known that Giambattista Vico argued already in the early 18th century that human civilization is based on the emergent capacity to imagine, through complex language, and thus to create something new.[2] Since the time when humans transcended basic physical impulses with the help of language, we have

1 David Christian, *Maps of Time: An Introduction to Big History* (Berkeley: University of California Press, 2004), especially 1-20, 505-511. The basic idea is summarized neatly in a 2014 textbook: "[…] there is a single thread that runs through the whole story: the emergence, over the 13.8 billion years since the universe appeared, of more and more complex things. Complex things have many diverse components that are arranged in precise ways so that they generate new qualities. We call these new qualities emergent properties". David Christian, Cynthia Stokes Brown, and Craig Benjamin, *Big History: Between Nothing and Everything* (New York: McGraw-Hill Education, 2014), 4. For a systematic theoretical exposition of emergence as combogenesis and of twelve major steps of emergence, see Volk, Tyler, *Quarks to Culture. How We Came to Be* (New York: Columbia University Press, 2017).

2 See e.g. Joseph Mali, *The Rehabilitation of Myth: Vico's 'New Science'* (Cambridge: Cambridge University Press, 2002).

been making our own cultural and social worlds.

Consciousness, society and history are mythopoetically constituted. If a myth is lived by people in their everyday practices and institutions, the resulting social order testifies to the truth of that myth. Hence, in order to know the human world, we must know its constitutive myths. For Vico, *mythos* and *logos* are mutually implicated. The Vicoan viewpoint needs to be rephrased, however, in terms of critical human sciences and epistemological, ethical and political pluralism. Critical science implies that beliefs can be wrong, even when they are constitutive of actions, practices and institutions. Pluralism means deep respect for other points of view, without relativism. As Nicholas Rescher explains:

> There is no good reason why a recognition that others, circumstanced as they are, are rationally entitled in their circumstances to hold a position at variance with ours should be construed to mean that we, circumstanced as we are, need feel any rational obligation to abandon our position. In so far as one is rational (and no doubt not all of us are) one cannot see the alternatives as indifferent.[3]

Temporal reflexivity sensitises us to recognize that the constitution of consciousness and society occurs also mythopoetically.[4] I argue in this paper that to be rational, the stories we are telling, involving anticipations of possible futures, must be open to criticism and revisable in a systematic fashion. Mythopoetic imagination can also be a means for critique of prevailing myths.[5] In complex pluralist societies, there are hegemonic struggles over constitutive myths, shaping both our explanatory stories about the past and scenarios about possible futures.[6] These myths can be addressed in various ways (empirical, theoretical etc) and at various levels of abstraction.

At the heart of BH is the common modern idea that with the development of science, God has been moved further and further away from the story of the origins of the cosmos (not to speak of causal interventions in it).[7] From this starting point different stories have been developed. I argue that a basic underlying myth of contemporary liberal-capitalist societies consists of three temporal tiers: deep cosmic scepticism if not desperation; various lessons drawn from this scepticism and related ideologies, such as Darwinism[8];

3 Nicholas Rescher, *Pluralism. Against the Demand for Consensus* (Oxford: Oxford University Press, 1993), 119-20.

4 Reflective consciousness, which has enabled our current levels of social complexity, can be seen as an emergent power made possible by the evolvement of metaphors and mental language and related social complexity rather late in human history (perhaps as late as during the Axial Age). This hypothesis may be controversial, but seems to me a plausible way of accounting for the existing archaeological and early historical evidence; Julian Jaynes, *The Origin of Consciousness in the Break-Down of the Bicameral Mind* (Boston: Houghton Mifflin, 2000). For an alternative account of roughly the same change, see Iain McGilchrist, *The Master and His Emissary* (New Haven CT: Yale University Press, 2012), 260-6. Tyler, *Quarks to Culture*, 117-119 [note 1] and Yuval Noah Harari, *Sapiens. A Brief History of Humankind* (New York: HarperCollins, 2014), ch 2, locate the origin of full language earlier than Jaynes (70,000 – 30,000 BCE rather than 25,000-15,000), but do not distinguish between full language and metaphorical language.

5 Chiara Bottici, *A Philosophy of Political Myth* (Cambridge: Cambridge University Press, 2007).

6 Robert W. Cox, *Approaches to World Order* (Cambridge: Cambridge University Press, 1996), e.g. 131.

7 Christian, *Maps of Time*, 22 [note 1]; thus God may be unlikely to frame 21st century debates about political theory, although this is an open question; see e.g. Heikki Patomäki, "From East to West: Emergent Global Philosophies – Beginnings of the End of the Western Dominance?," *Theory, Culture & Society* 19 no. 3, (2002), 89-111.

8 Darwin's theory of evolution is subject to many interpretations and it has been adopted to diverse purposes. It may be stressed that 'the struggle for existence' often brings about adverse consequences and is thus not good as such; or that 'survival of the fittest' is not the only mechanism of evolution but rather evolution is also about emergence of new forms of complexity. It may also be argued that when applied to society the mutation and selection conditions are social and more Lamarckian than Darwi-

and the capacity of technology and economic growth to bring some comfort and enjoyment to our short lives. An alternative cosmic storyline centres on the prospects of life, rather than death, and on the promises of our common evolvement also through learning. In my ideal-typical schemes, I associate these life- and learning-oriented ideas with pragmatism and critical realism, although many of these alternative notions are shared much more widely.[9] On the basis of the two ideal-typical storylines, I examine, compare and assess claims made within BH in terms of their scientific (*logos*) and narratological (*mythos*) plausibility. I show the ambiguities of the current BH narrative and envision a way forward.

On the narrative dimension of scientific explanations and futures scenarios

Temporality is fundamental to social actions and scientific explanations alike. According to Paul Ricouer, there is a unity of having-been, coming-towards and making present, since these are thought and acted upon together by the actors. This is the temporality of practical experience and action. The making-present of practical action stems from the anticipation of possibilities of transformative action producing outcomes on the basis of understanding of that which has-been (history). The horizon of action is thus inherently temporal.[10] Many political projects derive their motivation from the sense they render to our/their lives. Moreover, the appeal of grand narratives tends to be reinforced by awareness of one's own mortality.[11]

Scientific explanations too have a temporal dimension. A researcher draws a meaningful story from a diversity of temporal events that are constitutive of episodes and processes. Emplotment combines two temporal dimensions. By stipulating causal hypotheses, one captures the episodic dimension of temporality and creates components of explanation that go beyond mere chronicle. By grasping together the whole of the episode, one constructs a narrative or a story proper, a story which has a counterfactual sense of ending. As processes continue and history remains open, this sense of ending must be artificially created (the end is unreal as processes continue).

Every scenario is a story which has motivating power or charisma because it gives (or fails to give) meaning to the lives of individuals, groups and/or humankind. It is therefore very important to recognise the deep structures in our culture according to which we tell stories and construct myths. Structures of meaning determine capacity to generate stories. Structures of meaning may be relatively enduring and widely shared across cultures, even though they are subject to cultural variations, historical change and learning. When put together, lesser-scale stories may presuppose or form a grand or cosmic narrative of the origins, possibilities

nist. In this paper I purposefully associate Darwinism almost exclusively with those doctrines that tend to reduce evolution to 'struggle for survival' or something analogical and either accept this mechanism as 'natural' also in society (or as given in some other manner) or elevate it to a principle that generates normative good or 'optimal' outcomes (for instance free market doctrines).

9 In this paper pragmatism is largely associated with Charles Peirce and William James and their followers; and critical realism is associated with Roy Bhaskar and the network of scholars who have been active in the International Association of Critical Realism (IACR). I rely more on the latter than the former, but there are many commonalities between the two. It is also important to bear in mind that concepts such as emergence, causation, learning and normativity are best understood as open sites of discussions and developments, neither originating nor ending in any particular philosophy or theory. Instead of giving a long list of sources, I cite a specific article making the point that pragmatism covers much of the same ground as critical realism: Inanna Hamati-Ataya, "Beyond (Post)Positivism: The Missed Promises of Systemic Pragmatism," *International Studies Quarterly* 56, no. 2 (2012), 291-305.

10 Paul Ricoeur, *Time and Narrative Vol.1*, trans. Kathleen McLaughlin and David Pellauer (Chicago: The University of Chicago Press, 1984), 68-84.

11 See Hayward Alker, *Rediscoveries and Reformulations: Humanistic methodologies for International Studies* (Cambridge: Cambridge University Press, 1984), e.g. 105, 269-70.

and outlook for humankind. Every grand story locates the present context as part of a wider and structured temporal whole, thus organising our anticipations of possible futures at different scales of time. In our practical understandings and actions, grand stories become part of the Ricouerian triad of having-been, coming-towards and making present. Grand stories are in effect myths, i.e. "sacred" narratives explaining how the world and humankind came to be in their present form and what their future possibilities are.

Value-laden narratives affect our perceptions also in scientific contexts. The claim that scientific expert opinion is driven by sense-making and story-telling is evident in human sciences[12], but it is true also for natural sciences[13]. The plausibility of theories, successful tests, or predictive success do not unequivocally determine rational adoption of theories in sciences, not even in physics or chemistry (although many established textbook-level theories are rightly seen as being beyond reasonable doubt in the sense that they have passed all tests and work well for practical purposes).

The scientific process involves debates about cognitive values and philosophical theories. Cognitive values and philosophical theories are connected to our worldview more generally. This indicates that sense-making and story-telling is part of science, too, although many scientists do not pay enough attention to the philosophical, religious or ideological implications of their theories. Like any hypothesis, a hypothesis concerning emplotment should be made vulnerable to refutation and qualification, and open to the probative force of empirical evidence. The narrative hypothesis involved in scientific explanations and anticipations can be tested by various empirical and conceptual means. Do the elements of the story and their order correspond to what really has happened, is happening, or will happen? Hypotheses can be also tested at a more generic level, in terms of coherence and conceptual and theoretical plausibility, or in terms of their existential hypotheses (e.g. do the assumed entities, relations and mechanisms really exist?). Hypothesis-testing is not mechanistic, but requires interpretation and situated judgement.[14]

Because of the dependence of hypothesis-testing on interpretation and judgement, what is required is a strong ethics of scientific research. The basic realist manifesto is that "as scientists, that is members of a certain community, we should apportion our willingness or reluctance to accept a claim as worthy to be included in the corpus of scientific knowledge to the extent that we sincerely think it somehow reflects the way the world is"[15]. Science follows critical public procedures of verification and falsification, which are different from those of mere speculative imagination.

Yet scholars are also involved in the (re)production of social realities. As there can be no single decisive tests between theories, rationality and openness to learning become ethical and political matters also in a sense that goes beyond the mere virtue of truth. This point has to do with the ontology of time and temporality. The past is, in part, undetermined, and at some level will remain so. The meaning and characteristics of an event, episode or process depend on how the relevant processes turn out. For the same

12 E.g. Philip E. Tetlock, "Theory-Driven Reasoning about Plausible Pasts and Probable Futures in World Politics: Are We Prisoners of Our Preconceptions?," *American Journal of Political Science* 43, no. 2 (1999), 335-66.

13 See e.g. Larry Laudan, *Science and Values: The Aims of Science and Their Role in Scientific Debate* (Berkeley, CA: University of California Press, 1984).

14 A further complication is that it is possible that the same material can be ordered according to different actual or potential terminal consequences. All these temporal interpretations can be true with regard to the causal powers and sequences upon which they are elaborated. There may thus be many coherent and plausible stories to tell on the basis of the same material. See Heikki Patomäki, *After International Relations: Critical Realism and the (Re)Construction of World Politics* (London: Routledge, 2002), 141.

15 Rom Harré, *Varieties of Realism: A Rationale for the Natural Sciences* (Oxford: Basil Blackwell, 1986), 89.

reasons, we must rely on future-oriented narratives to describe contemporary events and on-going processes, the end of which can only be seen from a vantage point later than the moment of reflection or action within that process.[16]

The future, in turn, can only be studied in terms of scenarios of possible and likely futures. The future is real but not yet determined and our activities – including scholarly activities – take part in co-determining future events and episodes, potentially shaping processes at various scales of time.[17] Processes are open-ended and flowing, with one process capable of sliding into another, and with smaller processes combining to form larger processes. Reflexive involvement implies also ethical and political responsibility. The recognition of our ethical responsibility about the choice of stories is compatible with the scientific realist manifesto.

The basic mythologems of modern liberal-capitalist societies

In both natural and human sciences, the more canonical or dramatic the outcome of the story, the more appealing the story usually becomes. We know from psychological and social-psychological studies that missing links are quickly filled in with elements adopted from the pre-existing mythical and ideological scripts. More often than not, anticipations based on simple canonical or dramatic stories vastly inflate the likelihood of the expected course of events and processes.[18] Misleadingly canonised, generalised and inflated stories can serve as constitutive mythologem of a given social order (within which researchers operate), though they are also contested.

Arguably, the basic myth of liberal-capitalist societies of the late 20th century and early 21st century comprises three mythologems and temporal tiers: (i) the first tier is constituted by cosmic myths of desperation, involving the Copernican principle – “we don’t occupy a privileged position in the universe”[19] – and various narratives about how the story of humanity will inevitably end up in death, at some scale of time[20]; (ii) the second tier is motivated by cosmic desperation and involves a conviction that the spheres of life and culture either are or should be highly competitive, resulting in Darwinist or pro-market theories and ideologies[21]; (iii) the third tier

16 For a fuller account, see Heikki Patomäki, “On the Complexities of Time and Temporality: Implications for World History and Global Futures,” *Australian Journal of Politics and History* 57, no. 3 (2011), 339-52.

17 See also Heikki Patomäki, “Praxis, Politics and the Future: A Dialectical Critical Realist Account of World-Historical Causation,” *Journal of International Relations and Development* 20, no. 4 (2017), 805-25.

18 Thomas Gilovich, *How We Know What Isn’t So: The Fallibility of Human Reason in Everyday Life* (New York: The Free Press, 1991); Philip E. Tetlock, *Expert Political Judgement: How Good Is It? How Can We Know?* (Princeton: Princeton University Press, 2005), chs 2 and 3.

19 Astrophysicist Brandon Carter, in his contribution to a 1973 symposium honouring Copernicus’s 500th birthday, criticised over-reliance on the Copernican principle: “Although our situation is not necessarily central, it is inevitably privileged to some extent”. Brandon Carter, “Large Number Coincidences and the Anthropic Principle in Cosmology,” in *Confrontation of Cosmological Theories with Observational Data*, ed. Malcom Longair (International Astronomical Union, 1974), 291-8, accessed July 11, 2018, http://adsabs.harvard.edu/abs/1974IAUS...63..291C.

20 German scientist Rudolph Clausius claimed in the 1860s that everything will end in “heat-death” (*Wärmetod*). The second law of thermodynamics says roughly that entropy within closed systems should gradually become maximal and disorder should eventually reign. Entropy is a measure specifying the amount of disorder or randomness or something similar in a system that contains energy or information. Despite the confidence of Western scientific establishment in the truth of this gloomy cosmic story, the meaning and scope of the second law is ambiguous. Entropy has many meanings and we do not even know whether cosmos is a closed system. For a critical discussion on the development of the second law of thermodynamics, see Peter A. Corning and Stephen Jay Kline, “Thermodynamics, Information and Life Revisited, Part I: ‘To Be or Entropy’,” *Systems Research and Behavioural Science* 15, no. 4 (1998), 273-95.

21 In popular imagination, this mythologem is evident for instance in fictions about encounters with extra-terrestrial others depicted as evil beasts. In these stories, ETs are either as slaves

consists of belief in the blessings of technological progress and economic growth generated by capitalist market economy, providing sources of enjoyment and pleasure to us humans in our – and perhaps also in our children's – lifetimes.[22]

These ideas have deep philosophical roots. The allegedly value-neutral technical methods of empiricist science entail thorough scepticism about anything metaphysical or normative. God or values have no place in science. In the 18th century, David Hume explained that we should trust only our sense perceptions and be sceptical of anything else such as religious texts.[23] The sceptical sentiment grew stronger in the 19th century. Friedrich Nietzsche was among the first to fully articulate the devastating impact of empirical science on culture and civilization.[24] God is dead! We are alone on this insignificant planet. Nietzsche proclaimed further that no universal perspective is possible. Christianity, Kantianism, and utilitarianism are mere slave-moralities; we should be looking for something better. What is coming in the history of the next two centuries is the "advent of nihilism".[25] What Nietzsche really meant has been a source of endless discussions, but his prophetic texts clearly stress the nihilistic undercurrents of empirical science and modernity.

Contemporary cosmic myths of desperation are told in terms of theories of astrophysics, chemistry and theory of evolution. Nothing really matters, because most of things we see and experience are ultimately mere illusions. Even time and causation are not really real. Rather, the world is atemporal and mathematical. Usually only claims that can be expressed in the language of mathematics are truly scientific. The language of mathematics is technical, neutral and value-free.

Moreover, the origin of everything, the Big Bang, is itself a meaningless event. It may well be that numerous black holes produce new universes; or alternatively the universe may have emerged from nothing at all, for instance due to arbitrary quantum effects. The universe as a whole may be moving towards a heat-death or some other ultimate end-as-death, perhaps due to the ever-accelerating expansion of space. But also in shorter scales of time, the end looks inevitable. The solar system will come to an end with the life-cycle of the Sun; the Sun may collide with some other cosmic object; and the Earth may have only 500 million years left in the habitable zone of the system. Meanwhile, our planet seems constantly vulnerable to all sorts of cosmic and internal natural catastrophes. Finally, it seems increasingly likely that we humans will destroy ourselves already in the course of the 21st century.[26] The story is basically the same epic tragedy – without heroes – at all scales of time, from cosmic

of their passions or mindless followers of their genetically programmed codes of behaviour, independently of how technologically advanced they may be. For a critical analysis, see Heikki Patomäki, "Dialectics of Civilizations: A Cosmic Perspective," in *Alker and IR: Global Studies in an Interconnected World*, ed. Renée Marlin-Bennett (London: Routledge, 2008), 87-101.

22 Recently, this optimistic tier of the liberal-capitalist worldview has been defended by Steven Pinker, *Enlightenment Now. The Case for Reason, Science, Humanism and Progress* (London: Penguin Books, 2018); and Hans Rosling (with Ola Rosling & Anna Rönnlund) *Factfulness: Ten Reasons We're Wrong about the World – And Why Things Are Better than You Think* (London: Sceptre, 2018).

23 Hume was not consistent in his attitude towards religion or morality; he also wrote things like "the whole frame of nature bespeaks an intelligent author"; quoted in John C.A. Gaskin, "Hume on Religion," in *The Cambridge Companion to Hume*, ed. David Fate Norton (Cambridge: Cambridge University Press, 1993), 320. Although the fear of censorship and consequences might have led Hume to write contradictory statements, as a consistent sceptic Hume was unable and unwilling to deny the existence of God.

24 For Nietzsche's three phases and his diverse and ambivalent pursuits, see Maudemarie Clark, "Nietzsche, Friedrich," in *The Shorter Routledge Encyclopedia of Philosophy*, ed. Edward Craig (London: Routledge, 2005), 726-41.

25 Friedrich Nietzsche, *The Will to Power*, trans. Walter Kauffman and Reginald John Hollingdale (New York: Vintage, 1968), 3.

26 Martin Rees, *Our Final Century: Will Civilisation Survive the Twenty-First Century?* (London: Arrow Books, 2004).

to human.

Empiricism (positivism) relies on instrumentalism about knowledge. Knowledge is seen as something that can be used to control the world. Cosmic desperation associated with empiricist philosophical doctrines encourages short-termism and technical and preference-maximising orientation to the world. Moreover, empiricism tends to go hand in hand with reductionism (e.g. physicalism, biologism, individualism).[27] Repeatedly cosmic desperation has been connected with Darwinist ideologies, although desperation may also trigger an existentialist commitment to any ideology – such as nationalism or statist socialism – providing at least some hope about a better world, however unrealistic that may be given the underlying premises.[28] Most characteristically, however, the modern cosmic myths of desperation and their sceptical and empiricist underpinnings have supported ideas about competition of individuals and firms as the foundation of modern market society.[29] Scepticism, combined with the reduction of the necessary and the possible to the actual, generates among other things 'there is no alternative' thinking[30] and the tendency to write Whig-histories about the inevitable progress towards the present[31]. Reductionism suggests either value subjectivism (though individuals may of course behave morally for whatever arbitrary reasons) or outright moral nihilism.

A critique of the prevailing mythologeme: there is an alternative

From a methodological point of view, the prevailing

27 For a consistent empiricist, what exists is "my sense-experiences". The objects of these sense-experiences are atomistic events. Other perceiving individual minds may be allowed to exist as well. This kind of empiricist ontology encourages epistemological reductionism (e.g. physicalism, biologism, individualism). For example in neoclassical economics, there is a tendency to reduce macroeconomics to microeconomics focussing on individual decision-makers; to use psychology to explain why individuals are what they are; and to use socio-biology to explain psychology.

28 An interesting case is Louis Althusser, whose commitment to the true meaning of Marx's theory, his "anti-humanism", and his loyalty to the Communist Party despite its hierarchies, exclusions and violence can be read as an existentialist ethico-political commitment in an otherwise nihilist world. Five years after killing his wife, Althusser wrote memoirs where he exclaims his desperation and repeats, in a Freudian language, many of the points made by Nietzsche, "Does one have to point out that, in addition to the three great narcissistic wounds inflicted on Humanity (that of Galileo, that of Darwin, and that of the unconscious), there is a fourth and ever graver one which no one wishes to have revealed (since from the time immemorial the family has been the very site of the *sacred* and therefore of *power* and of *religion*). It is an irrefutable fact that the Family is the most powerful ideological State apparatus." Louis Althusser, *The Future Lasts Forever: A Memoir*, trans. Richard Veasey (New York: The New Press, 1993), 104-105.

29 This attitude is formalized in mainstream neoclassical economics, which revolves around the concept of "perfect competition". Ben Fine summarizes its development: "[All t]his was done through an extraordinary reductionism in which all else was sacrificed in order to obtain the desired results, an implosion of *homo economicus* upon itself". Ben Fine, "Neoclassical Economics: An Elephant Is Not a Chimera but Is a Chimera Real," in *What Is Neoclassical Economics? Debating the Origins, Meaning and Significance*, ed. Jamie Morgan (London: Routledge, 2015), 186.

30 As Roy Bhaskar explains: "Ontological reductionism transposed to the human zone has particularly damaging consequences. In perfect resonance with the empiricist concept of science as a behavioural response to the stimulus of given facts and their constant conjunctions, society is conceived as composed of individuals, motivated by given desires and conjoined (if at all) by contract. Reason is reduced to the ability to perform an optimizing or satisficing operation and freedom consists in its unimpeded exercise. [….] It is the ideology of the market place and more generally of the established order of things, of TINA (there is no alternative)." Roy Bhaskar, *Reclaiming Reality: A Critical Introduction to Contemporary Philosophy* (1989; repr., London: Routledge, 2011), 10.

31 Herbert Butterfield developed this concept in his *The Whig Interpretation of History* (London: G.Bells & Sons, 1959, orig. published 1931). According to Butterfield, the Whig history leads very quickly to the division of the world into supporters and opponents of the story of progress toward the present, goodies and baddies, and the narrative of heroes from this perspective. Pinker and Rosling, mentioned in note 22, are contemporary examples of Whig-histories.

scientific stories about the ultimate fate of humanity seem to involve various fallacies and misleading assumptions. Most common are (i) the assumption of closed systems and (ii) overconfidence on the currently prevailing scientific theories. Both are rooted in the empiricist (positivist) philosophy of science, which is moreover self-nullifying in denying causal agency and its role in science.[32] Moreover, over-reliance on mathematics can further feed the sense of certainty encouraging dogmatism.

In reality, systems are open. Open systems interact with causal processes not confined within them and often involve qualitative changes and emergence. The openness of systems means that everything is historical and evolving, (possibly) including even the laws of physics. New constellations, properties and powers can emerge. Moreover, science is historical, processual and open-ended. It is dependent on the antecedently established facts and theories, paradigms and models, methods and techniques of inquiry. For a particular scientific school or scientist, these provide the material from which new ideas, theories etc are forged. On that basis researchers produce – in a particular geo-historical context – new facts and theories, paradigms and models. The process of scientific change does not leave earlier conceptualisations intact. Something is lost and something new is created.[33] In some sense Newtonian mechanics may describe a special case of the theory of relativity, but the latter includes also a novel conception of space-time (in general relativity, the effects of gravitation are ascribed to spacetime curvature instead of a force). The ultimate nature of space and time remains disputed in contemporary science.

Many contemporary scientists proclaim that there is nothing special about this universe of ours. It is a mere result of a cosmic lottery or some sort of Darwinist selection. There are countless (if not an infinite number of) disconnected universes; this one of ours just happens to be life-friendly, and only for the time being.[34] The process of biological evolution is arbitrary; humanity is an accidental outcome. A key problem with speculations about cosmic selection or lottery is that these presuppose the existence of something that probably can never be observed. Thereby they also radically multiply beings, thus violating even the most cautious and qualified interpretation of Ockham's razor (to which empiricism and positivism are committed).[35] Although it is in principle possible that this line of line of research will yield falsifiable hypothesis at some point, a further problem is that failure to verify predictions can be easily explained away at no cost to the speculation, given the indirect nature of possible hypotheses.[36] Application of the Copernican principle or Darwinism to speculative universes can thus be misleading. A risk of relying on speculations about countless universes is that science comes to be replaced, quite unreflexively, with stories derived merely from traditional myths and ideology.

We can now start to see why scenarios about an inevitable end-in-death are rather implausible from a scientific point of view, however appealing as stories (according to Isaac Asimov "the conviction that the whole universe is coming to an end […] is an old one, and is, in fact, an important part of Western tradition"[37]). Scenarios about what will happen in

32 See Roy Bhaskar, *Scientific Realism and Human Emancipation* (London: Routledge, 2009), 8, 16-19, 32, 71, 153.

33 For a deeper and more sophisticated account, see Bhaskar, *Scientific Realism*, 47-62 [note 32].

34 For different but insightful discussions, see for instance Paul Davies, *The Goldilock's Enigma: Why is the Universe Just Right for Life?* (London: Allen Lane, 2006), ch. 8; Martin Rees, *Before the Beginning: Our Universe and Others* (London: Simon and Schuster, 1997), 251–69; Leonard Susskind, 2006. *The Cosmic Landscape: String Theory and the Illusion of Intelligent Design* (New York: Little, Brown and Co., 2006), 293–376.

35 See Heikki Patomäki, "After Critical Realism? The Relevance of Contemporary Science," *Journal of Critical Realism* 9, no. 1 (2010), especially n. 81, 83-4.

36 Lee Smolin, *Time Reborn* (London: Penguin Books, 2014), 250.

37 Isaac Asimov, *A Choice of Catastrophes: The Disasters that*

Empiricism / positivism / Nietzsche	**Critical realism / pragmatism**
• Value-neutral technical methods of empiricist science → skepticism about anything metaphysical or normative, but often scientist certainty about science. • God is dead! We are alone on this insignificant planet! • Knowledge is a tool of control and power. • Changes are non-real, illusionary or minimal. • Reductionism → tendency toward atomism. • Reason is reduced to the ability to perform an optimizing or satisficing operation; and freedom consists in its unimpeded exercise.	• Open systems & emergence is real → history is open-ended – science itself is an open-ended process • Everything is historical and evolving, including our agency, will and intentions – rationality is normative & things matter → ethical and political learning • Freedom can be increased by replacing unnecessary (and often misrepresented) sources of causal determination with more wanted and needed sources – self-determination – good life • History is not meaningless; the rational *telos* of history is dialogical and evolves with history. • Change & emergence in world society: transformative political agency.

Table 1: Ideal-typical philosophical differences (logos)

the next thousands, millions, or billions of years are speculative and the more so, the further we reach. There are two reasons for this: the openness of systems (ontology) and the open-ended nature of the process of scientific learning (epistemology). There are thus *ontological limits* to the predictability of cosmic futures. *Epistemologically*, the purpose of science is not to produce timeless dogmas; rather science is an open-ended process characterised by differences of opinion, pluralism and learning. In both ways, the future is open.[38]

The tacit assumption of projecting long-term futures on the basis of currently accepted scientific theories is that time will leave those theories intact. Many scientists seem unable or unwilling to take on board the lessons of the history of science as a changing and evolving social practice, to see themselves as part of a long process of scientific developments. However, in a mere 1/1000th of a million years our science and technology is bound to look very different. Just imagine how our science and technology will look, say, in the 32nd century. The future developments are likely to accord with Arthur C. Clarke's famous three laws[39]:

1. When a distinguished but elderly scientist states that something is possible, she is almost certainly right. When she states that something is impossible, she is very probably wrong.
2. The only way of discovering the limits of the possible is to venture a little way past them into the impossible.

Threaten Our World (London: Arrow Books, 1981), 13.

38 Systems are always open and closed only to a degree. Future can be analysed in terms of conditional and more or less likely possibilities of becoming. The closer we get to a given point in the future, the more shaped and structured it is. Moreover, it is possible to assess the intersubjective-qualitative probability of different scenarios and revise our scenarios in light of new evidence and developments. Heikki Patomäki, "Exploring Possible, Likely and Desirable Global Futures: Beyond the Closed vs. Open Systems Dichotomy," in *Scientific Realism and International Relations*, ed. Jonathan Joseph and Colin Wight (Palgrave: London, 2010), 147-166.

39 Discussed in Arthur C. Clarke, "Hazards of Prophecy: The Failure of Imagination," in *Profiles of the Future: An Inquiry into the Limits of the Possible* (London: Indigo, 2000), 19-26.

3. Any sufficiently advanced technology is indistinguishable from magic.

When new scientific possibilities are opened up and new advanced, "magic-like" technologies developed (enabling also new paths of research), scenarios about our cosmic fate at different scales of time are very likely to change.

An alternative mythologeme: the power of life and culture

It is possible to use our imaginative capacities to develop alternative and scientifically and mythopoetically more plausible storylines.[40] In this section, I present a life- and culture-oriented storyline that accords at least as well with the findings of contemporary science as the liberal-capitalist storyline. Similarly to the latter, the alternative can be understood as an attempt to build a coherent and plausible story out of somewhat diverse elements, that is, as an ideal-type.

To begin with, the currently standard version of the Big Bang theory is unlikely to be the last word. The homogeneity of the cosmic background radiation is habitually interpreted as evidence for a singularity and the subsequent period of huge cosmic inflation at the beginning of the universe. However, if time did not start then, there are plausible alternative explanations (and new ones can be created in the course of future scientific processes). For instance, in the beginning of this universe, there may have been no point of singularity from which everything began, but rather some continuity from a predecessor universe.[41] There are also many other reasons to think that time is real, continuous and non-finite, and also as global and irreversible.[42]

Moreover, in this alternative story, our cosmos is singular and unique. There is only one universe at a time. While laws of physics may appear stable in the contemporary cooled-down universe, they are not immutable (if and when the relational structures change, so do laws). Causation, emergence and change are real. Everything is historical and evolving. Hence, physics and chemistry could well learn a few things from geology, life sciences and human sciences.[43] Moreover, emergent layers such as conscious experience, agency, will and intentions are real and causally efficacious.

40 For an overview of alternative views, for instance those developed by Kant, Hegel, various critical theorists and American pragmatists such as Peirce and James, see Zachary Stein, "Beyond Nature and Humanity. Reflections on the Emergence and Purposes of Metatheories," in *Metatheory for the Twenty-First Century: Critical Realism and Integral Theory in Dialogue*, ed. Roy Bhaskar, Sean Esbjorn-Hargens, Nicholas Hedlund & Mervyn Hartwig (London: Routledge, 2015), 35-68.

41 "If the singularity is absent, then the sufficient reason for choices of initial conditions and laws may lie in the world before the big bang." Roberto M. Unger and Lee Smolin, *The Singular Universe and the Reality of Time* (Cambridge: Cambridge University Press, 2015), 402.

42 The preferred cosmic time is not absolute (like it was for Newton) but relational. In a relational spacetime theory space is dependent on the relations between bodies; and time is dependent on events and processes. The preferred cosmic time is determined through the shape dynamics of the whole. Shape dynamics is an approach that has advanced during the 2010s and has a physical arrow of time due to the growth of complexity and the dynamical storage of locally accessible records of the past. Julian Barbour, Tim Koslowski and Flavio Mercati, "Identification of a Gravitational Arrow of Time," *Physical review letters* 113, no. 18 (2014). 181101. Cosmic time in this sense is consistent with the relativity of simultaneity in any local regions of spacetime. Unger and Smolin, *The Singular Universe*, 188, 420-1 [note 41]. Carlo Rovelli accepts that it is possible to distinguish the time that guides the rhythm of processes from a real universal time, and thus writes that "the point of view of Smolin, Ellis and Maroun is defensible". Rovelli, however, accuses Smolin of forcing the world to adapt to our intuition and contrasts that with "what we have discovered about the world". This is a *petitio principii*, however. The question that remain open is: what is it that we have discovered about the world? Carlo Rovelli, *The Order of Time* (London: Allen Lane, 2018), 190-1, n.14.

43 See Unger and Smolin, *The Singular Universe* [note 41].

Account 1: Meaninglessness and illusions prevail	**Account 2: Reality involves life, consciousness and active agency**
• Big Bang: original singularity, possibly coming out of nothing, was also the beginning of time. • The Big Bang itself is a meaningless and arbitrary event – numerous black holes produce new universes → multiverse/Darwinism – alternatively the universe may have emerged from nothing at all, due to arbitrary quantum effects • Cosmos is indifferent or hostile to us humans. • Ultimately time and causation are illusions; and agency is illusionary, redundant or marginal.	• There is only one universe at a time; reasons for the choices of initial conditions and laws lie in the world before the big bang. • Time, causation, emergence and change are real; making also life possible. • Cosmos is hospitable to life, although interpretations about the meaning and extent of this hospitality vary. • Emergent layers such as conscious experience, agency, will and intentions are also real and causally efficacious.

Table 2: Contrastive accounts about the beginning and nature of cosmos

Life is not only real but it has generated new emergent powers on Earth and possibly elsewhere. Cosmologists have come to realise that complexity, life and billions of years of evolution in stable environment require very specific circumstances. For instance, all four basic forces of nature are in many ways implicated in the life story. Changing the strength of any of them, even by a small amount, could render the universe sterile. To give a more specific example, if certain very specific nuclear resonances in the nuclear physics of carbons were a little different, then the heavier elements could not build up in the interiors of red giant stars. The universe would contain only hydrogen and helium, and life would be impossible. The list is long.[44]

Overall, our singular and unique cosmos seems hospitable to life, although interpretations about the meaning and extent of this hospitality vary.[45] A plausible alternative storyline about the future of the cosmos revolves around life and its possibilities rather than death. This account does not exclude individual death or the possibility of a collective catastrophe, but it stresses reflexivity about the poetic aspect of catastrophe-stories. The Greek word *katastrophē* meant “to overturn” or “turn upside down”. In dramas, the catastrophe is the final resolution or climax in a poem or narrative plot, which brings the piece to a close. Although the word “catastrophe” has come to be associated with tragic endings rather than with happy ones, in a comedy the climax is a happy ending. It is only in tragedy that the climax of the story means

44 See e.g. Paul Davies, *The Goldilocks Enigma: Why is the Universe Just Right for Life?* (London: Allen Lane, 2006), 151-71; or Martin Rees, *Our Cosmic Habitat* (Princeton: Princeton University Press, 2017).

45 Interestingly, Unger and Smolin, *The Singular Universe*, 531-2 [note 41] disagree about the extent to which the universe can be seen as hospitable to us. They agree that mostly nature is indifferent about us; that each individual is going to die; and that reverence for the universe is unhealthy power worship. Smolin stresses, nonetheless that their “natural philosophy” is also a bearer of good news. Neither we nor the universe is computational and our experiences accord with the nature of reality. We are part of the whole of nature and cosmos. Christian de Duve in turn shares the agnosticism of Unger and Smolin and yet argues that “available clues support the assumption that our universe is such that generation of life was obligatory, probably in many sites and at many times”. Our universe is “pregnant with life”. Christian De Duve, “How Biofriendly is Our Universe?,” in *Fitness of the Cosmos for Life: Biochemistry and Fine-Tuning*, ed. John D. Barrow et.al. (Cambridge: Cambridge University Press, 2008), 194-5.

the death of the hero (possibly together with many others). What is also important is that tragedy has a future-oriented purpose. The unexpected discoveries and sudden turns can generate a purifying or clarifying *katharsis* among the audience[46], perhaps even some metaphysical comfort through experiencing human sacrifice in art[47]. *Katharsis* can thus be seen as a form of comfort; correction to excessive emotions such as pity or fear; or restoration of psychic health.

Comedy is life- and future-oriented. Comedy can be understood as the mythos of spring: the story of a new, better society replacing the old, absurd one. In comedy, there can be misunderstandings, illusions and actions with unforeseen consequences and some characters can also be represented in satirical light, but in the end things tend to turn out fine. Moreover, tragedies and comedies can also be mixed in various ways.[48] Although nothing truly terrible happens in a tragicomedy, the end often involves unfulfilled desires and tragic feelings of the impossibility of a fully happy ending. This may bring tears – perhaps in the midst of laughter – to the eyes of the spectator. For these reasons, comedy is perhaps the most humane of the three main genres of narratives and plays. It involves the likelihood of a happy ending, but does not exclude the possibility of unfulfilled desires or tragic outcomes.[49]

Consider for instance internal and cosmic planetary catastrophes (violent earthquakes or volcanic eruptions, major asteroid or comet impacts) that seem to threaten our future. These are rare phenomena and their risks can be addressed by means of future-oriented planetary co-operation. Over time, our technological and organizational capacities to tackle these and other dangers will increase.

The danger of self-destruction in the course of the 21st century seems more serious, for instance by means of weapons of mass destruction or ecological collapse. The possibility of a tragic global military catastrophe is real and appears once again, after the end of the Cold War, increasingly likely. Disintegrative tendencies and processes of conflict-escalation prevail due to the current constellation of forces in global political economy. They may be gradually assembling conditions for an ever bigger crisis – or a full-scale global catastrophe. Yet there is also a rational tendential direction to world history, more firmly based than contingent events and processes.[50]

The rational tendential direction is grounded in collective human learning. Three elements of rationality constitute the tendential directionality of world history. The first is truth, involving criticism of falsehoods and attitudes that sustain falsehoods. The second concerns overcoming contradictions through collective action and common institutions. Lastly, the third involves normative universalizability and our capacity to resolve social conflicts. Transformations toward a rational tendential direction is not automatic, it is realized through transformative praxis, which depends among other things upon the rationality of participating actors. The minimal meaning of rationality is openness to reason and learning.

46 Aristotle was of the opinion that tragedy must be simple and thus a well-constructed plot involves only a single catastrophe. "In the second rank comes the kind of tragedy which some place first. Like the Odyssey, it has double threat or plot, and also an opposite catastrophe for the good and the bad." Aristotle, *Poetics*, intro by Francis Fergusson (New York: Hill & Wang, 1961), XIII, 77.

47 This was early Nietzsche's interpretation of Greek tragedy, which he proposed as a solution to the question "how can we overcome nihilism?". See Julian Young, *The Death of God and the Meaning of Life* (London: Routledge, 2003), 44-56.

48 See Riikka Kuusisto, "Comparing IR Plots: Dismal Tragedies, Exuberant Romances, Hopeful Comedies and Cynical Satires," *International Politics* 55, no. 2 (2018), 160-176.

49 I compare different possible story-lines concerning the future of global political economy and security in Heikki Patomäki, *The Political Economy of Global Security: War, Future Crises and Changes in Global Governance* (London: Routledge, 2008), 217-21.

50 See Heikki Patomäki, *Disintegrative Tendencies in Global Political Economy: Exits and Conflicts* (London and New York: Routledge, 2018).

Preferred storyline 1: tragedy (end)	Preferred storyline 2: (tragi)comedy
• The story is basically the same epic tragedy without heroes at all scales of time. – tragedy without *katharsis* • A possible interpretation of *katharsis*: some (desperate) metaphysical comfort through experiencing human sacrifice in art (as in early Nietzsche). • The sense of tragedy is typically combined with a Whig history about inevitable progress to the present (a typical story involves instrumentalist accounts of science, rationality as optimization, hedonism, and consumerism). • Ultimate end in death.	• Explanations of different outcomes, episodes and processes call for different plots and their combinations. • *Katharsis* can be seen as a form of comfort; correction to excessive emotions such as pity or fear; or restoration of mental and social health. • Tragicomedy: contingent developments, the end often involves unfulfilled desires and sense of impossibility of a fully happy ending. • Comedy is humane because it involves the possibility of happy ending, but does not exclude tragic outcomes or unfulfilled desires. • History is open, stories continue.

Table 3: Ideal-typical contrastive plots (mythos)

Once context-specific learning has occurred and a reasonable concrete direction set, the next logical step is the process of constructing transformative agency and building better common institutions to transform conflicts and tackle common problems.[51]

Our cultural evolution has created also other problems. Since the industrial revolution, human activities have affected biosphere and climate on a planetary scale. So far, the consequences have been negative, as shown by the mass-extinction of species and anthropogenic global warming. Yet the role of humanity may well be more life promoting and ethical in the future. A global climate regime has been in the making for a quarter of a century now. The flaws and deficiencies of the Kyoto Protocol and Paris UNFCCC Agreement notwithstanding, the gradual and troubled evolvement of climate governance indicates how the futurized nature of the present is changing. Reflexive self-regulation occurs through increased knowledge about the way natural and social systems work and generate effects, not only now, but also in the future.[52] Global climate governance is an attempt at reflexive self-regulation that consciously aims at homeostasis by regulating the planetary environment. The aim is to maintain a relatively constant temperature to counter the effects of greenhouse gases. This process will take time; a lot depends on the timing of adequate responses.

While constrained by real natural processes and social structures, the planetary future does not just happen but becomes increasingly something that various actors – including “we”, whoever this we may refer to – make of it. There is also a deeper, a more cosmic aspect to this transformation. James Lovelock developed a controversial hypothesis in the 1960s and 1970s according to which the systems of life form a complex interacting system that maintains itself in the long run, through homeostatic feedback loops, life-friendly climatic and biogeochemical conditions on

51 Patomäki, *Disintegrative Tendencies*, 116-27 [note 50]; see also Heikki Patomäki, “Emancipation from Violence through Global Law and Institutions: A Post-Deutschian Perspective,” in *Pacifism*, ed. Johan Kustermans, Timothy Sauer, Didier Lootens and Barbara Segaert (Palgrave MacMillan: London, 2019).

52 For a general account about how the futurized nature of the present is changing, see Heikki Patomäki “On the Complexities of Time and Temporality: Implications for World History and Global Futures,” *Australian Journal of Politics and History* 57, no. 3 (2011), 339-352.

Earth.[53] However, both Gaian (negative) and non-Gaian (positive) feedbacks are likely to evolve in response to global warming. Hence, there is no automatic homeostasis, at least not in the scale of 10^2 of years or less.[54] If there is to be homeostasis, it must be created by means of conscious, future-oriented interventions into the ways in which our socio-economic systems work and are shaping Earth's climate and biosphere.

We humans have come to be deeply involved in Earth's future developments. Earth has nurtured life for a long time, continuously for more than three billion years. In a sense, the planet is now becoming conscious of itself through the gradual rise of human reflexive self-regulation aiming at maintaining life-friendly climatic and biogeochemical conditions. What is more, reflexive self-regulation may contribute to improving the underlying social conditions of ethico-political learning. Collective learning reflexively shaping our common planetary conditions and the direction of world history as a whole can mean, among other things, that the sphere of human freedom is gradually widening – a process that may have much wider significance. The degree of freedom can be increased by replacing particular unnecessary and often misrepresented causal sources of determination with more wanted, needed and better-understood sources of causal determination, classically implying attempts to increase one's autonomy as self-determination.[55] These are steps in "the long march of mankind toward its unity and better control of its own fate"[56].

From the point of view of grand narratives, what is interesting is the possibility that emergent layers of life and culture may gradually assume an increasingly important role in the process of cosmic evolution. Biological reality is multi-layered, hierarchically organized and involves interdependent functional synergies and higher-level controls, making purposive behaviour and, ultimately, also culture and consciousness possible. Complex systems of life have shaped the chemical composition and development of planet Earth for more than three billion years, setting it to a current path of development that is systematically off its non-living physical state of existence. The Earth is blue because it is teeming with life.

By cautiously generalising from the experiences of the Earth, it is conceivable that in the future life and consciousness will play a (co-)formative role in our galaxy and possibly even in the universe as a whole. From this perspective, British-born theoretical physicist and mathematician Freeman Dyson has proposed a vision that is best read as a plausible counter-hypothesis to the heat-death scenario:

> The greening of the galaxy will become an irreversible process. […] The expansion of life over the universe is a beginning, not an end. At the same time as life is extending its habitat quantitatively, it will also be changing and evolving qualitatively into new dimensions of mind and spirit that we cannot now imagine.[57]

This scenario of the greening of the galaxy sets a future project for humanity; the expansion of life and culture into space may be one of the chief tasks awaiting humankind. There may be other sentient and conscious beings, but even in that case, the greening of the galaxy would occur through cultural and technological means in a post-biological universe.[58] This implies that the future of cosmos is not only about

53 James Lovelock, "Gaia as seen through the Atmosphere," *Atmospheric Environment* 6, no. 8 (1972): 579-80; see also James Lovelock, "Hands Up for the Gaia Hypothesis," *Nature* 344 (1990), 100-2.

54 James Kirchner, "The Gaia Hypothesis: Fact, Theory, and Wishful Thinking," *Climatic Change* 52, no. 4 (2002), 391-408.

55 Bhaskar, *Scientific Realism and Human Emancipation*, 115 [note 32].

56 In the words of the Keynesian economist Robert Triffin, *Our International Monetary System: Yesterday, Today, and Tomorrow* (New York: Random House, 1968), 179.

57 Freeman Dyson, *Disturbing the Universe* (New York: Basic Books, 1979), 236-7.

58 Steven J. Dick, "The Postbiological Universe and Our Future in Space," *Futures* 41, no. 8 (2009), 578-80.

There is no alternative (TINA)	Emancipatory transformations are possible

• Skepticism, combined with the reduction of the necessary and the possible to the actual ('actualism'), generates 'there is no alternative' thinking
  o this is also the origin of Whig-histories
• Reductionism suggests either value subjectivism (though individuals may behave morally for whatever arbitrary reasons) or outright moral nihilism.
• Reductionism turned into ideology of markets and established order of things (of TINA, there is no alternative).
• Life and society are about competition: Darwinism – market-society – capitalism.
• Some improvements may be possible, but only within the prevailing institutional liberal-capitalist order.
	• The rational tendential direction of world history is grounded in collective human learning.
	• Three elements of rationality constitute the tendential directionality of world history:
	  1. Truth, involving criticism of falsehoods and attitudes that sustain falsehoods.
	  2. Normative universalizability and our capacity to resolve social conflicts.
	  3. Overcoming lacks, contradictions etc through collective action and common institutions (revising old building & new institutions).
	• The possibility of development of new cooperative capacities, needs and ethico-political horizons ("new dimensions of mind and spirit that we cannot now imagine").

Table 4: Ideal-typical ethico-political differences

expansion of life but also about society and culture, about ethics and politics. More than that, structures and processes at that level of reality can create new dimensions of mind and spirit, through collective learning of humankind (and other species).

Pragmatism and critical scientific realism encourage cosmic hopefulness, thereby facilitating scientific learning and progress. Astrobiology will be a key area of learning in the next few decades and centuries. We are likely to learn much more about the conditions and determinants of life in the universe.[59] This learning will shape our future-scenarios and assessments of their plausibility. Whereas the prevailing mythologeme of liberal-capitalist societies is characteristically associated with parametric (environment is seen as fixed in relation to one's individual choices) and strategic modes of consciousness (other subjects are recognised only as strategic players and the point remains to optimise under constraints)[60]; in this alternative mythologeme, actors:

- recognise each other as equal subjects positioned in social relations.
- are capable of recognising social ills and contradictions at the level of wholes.
- and are capable of organizing collective actions and building common institutions to absent ills and overcome contradictions.

Cosmic hopefulness encourages attempts to build trust, solidarity and ethico-political commitments. Successful organization of collective action requires communication to feed the development of trust and solidarity. Success in these endeavours is contingent on agency and eco-socio-historical conditions. Because of contingency, success is not guaranteed: negative outcomes are possible. In this alternative mythologem, types of plots can be combined in many ways to understand particular episodes or processes. A happy ending is in no way guaranteed but achievable, even if it may involve unfulfilled desires and tragic feelings of loss. Hopefulness can exhibit itself at different scales of time. Some outcomes may be negative, tragic and

59 Steven J. Dick, *Astrobiology, Discovery, and Societal Impact* (Cambridge: Cambridge University Press, 2018).

60 For these modes, see Jon Elster, *Logic and Society* (Chichester: John Wiley & Sons, 1978), ch 5.

even terminal in relation to a particular process or processes; while wider processes will always persist. The more a hopeful story stresses the negative, tragic and terminal phases, the closer it gets to Christian and Marxian eschatology; and thereby it becomes more liable to accepting unnecessary suffering and violence.[61]

Analysing and assessing the Big History storyline

At first look, the current version of BH appears consistent with the life- and learning-oriented storyline. David Christian's grand narrative about our origins is meant to stand in for the role played by mythical narratives in early human societies.[62] The idea is that deep stories are important in establishing meaning and identity. Ethical and political projects derive their motivation from the sense they render to our lives. The explicit purpose of BH is to help to establish a widespread awareness of belonging to a planetary whole.[63] The hope is that the modern cosmic story of our origins will forge a global we-feeling and cooperation in the world plagued by global problems. The bulk of this narrative concerns increasing complexity on the life-friendly planet Earth. New properties and powers come to being through major turning points. BH not only frames world history in cosmic terms and imagines a future world community, but it is also systematically critical of Eurocentrism and other forms of centrism. By evoking innovative myths about shared human existence and destiny, BH helps to articulate a rising global imaginary for transformative and progressive politics in the 21st century.[64] BH appears thus committed to a transformative planetary vision and stresses the role of biological and cultural evolution and increasing complexity.

However, a closer look reveals ambiguities. BH contains some elements from both storylines – and not in an entirely unproblematic way. This raises the question of whether it is possible that the BH tale could turn out to be counterproductive. At the deepest level, Christian and his co-authors seem committed to the standard version of the Big Bang cosmology as the last word of science so far, even if they are agnostic about the details of the origins of the universe: "We don't really know what [the universe] came out of or if anything existed before the universe". What is more certain is that when the universe emerged from "a vast foam of energy, it was extremely simple".[65] These reservations and qualifications notwithstanding, Christian, Brown and other BH authors affirm the notion that the original singularity, possibly coming out of nothing, was followed by cosmic inflation. The wider cosmic context of the Big Bang is a multiverse

61 For example, Wagar's *A Short History of the Future* (3rd edition, Chicago: Chicago University Press, 1999) involves a nuclear war in the 2040s and the death of seven billion people. The scenario is based on the assumption that only a tragic global catastrophe can spell an end to the system of nation-states and capitalist world economy and lead to global-democratic transformation. Ironically, the nuclear war of 2044 means a happy ending to the process of global warming. In this story, transformative agency lies in a world political party. In the 2050s, there is a debate in the party between the pluralists, preferring non-violent methods and the possibility of staying outside the World Commonwealth, and the Leninists. The Leninists carry the day. The world is united under a democratic-socialist world state, but at the expense of an additional three million casualties.

62 World history, world systems theory and related attempts have preceded and paralleled Big History in Christian's sense. For a brief history of Big History, see David Christian, "What is Big History?," *Journal of Big History* 1, No:1 (2018), 4-19 (available at http://dx.doi.org/10.22339/jbh.v1i1.2241).

63 Already H.G.Wells's *Outline of History* (originally published in 1920) was explicitly motivated by a desire to unify humanity in terms of a common planetary history located in a cosmic setting.

64 Heikki Patomäki, and Manfred Seger, "Social Imaginaries and Big History: Towards a New Planetary Consciousness?," *Futures* 42, no. 10 (2010). 1056-63; Heikki Patomäki, "On the Possibility of a Global Political Community: The Enigma of 'Small Local Differences' within Humanity," *Protosociology. An International Journal of Interdisciplinary Research* 33, no. 1 (2017), 93-127.

65 David Christian, *Origin Story: A Big History of Everything* (London: Allen Lane, 2018), 11.

or Darwinist selection of universes.[66] This is the first tier of the liberal-capitalist myth.

For non-experts in cosmology, it is of course reasonable to rely on the currently prevailing scientific opinion, even when it is non-consensual. It is beyond reasonable doubt that the early universe was radically smaller and much simpler than the current universe. Reliance on the standard Big Bang theory satisfies some requirements of a reasonable appeal to scientific authority.[67] However, claims about the beginning of time, multiverse and Darwinist selection of universes are speculative. Whatever evidence there may be is usually circumstantial and indirect at best. The hypothesis of cosmic inflation seems to accord well with the evidence (especially background radiation), but rival hypotheses can explain the same evidence.[68] Moreover, we know that also evidence-based scientific theories are open to change and that scientific expert opinion can be driven by sense-making and story-telling. While it goes without saying that we cannot settle scientific disputes at the philosophical or mythological level only, differences at that level matter, especially in contexts where evidence is ambiguous and there are competing hypotheses, theories and speculations.

BH is an impressive achievement, and yet it can be argued that the theoretical and practical commitments of BH are not entirely consistent. Firstly, BH is in important part motivated by the "sense of disorientation, division and directionless" that characterises our modern world.[69] BH criticizes excessive specialisation and fragmentation of sciences and humanities. Christian writes daringly about "a return to the goal of a unified understanding of reality, in place of the fragmented visions that dominate modern education and scholarship".[70] However, many prevailing theories and speculations about the origins and nature of the universe stem from theories that contradict the views and aims of BH. In its current mainstream form, science is habitually premised on reductionism. This is evident for instance in numerous attempts to develop a theory of everything ("a set of equations capable of describing all phenomena that have been observed, or that will ever be observed").[71] What is more, the abstract logical time of mathematical theories in fields ranging from physics to economics turn time into a quasi-spatial dimension and represent reality as atemporal or at least ahistorical.

Second, and perhaps more importantly, BH, as articulated so far, seems to share several end-in-death scenarios with the liberal-capitalist worldview. Entropy will increase and space expand until a few "lonely beacons of light will find themselves in a galactic graveyard"[72] – and finally these lonely beacons will perish too. The end of our solar system will come much sooner and well before that, the Earth will become uninhabitable. "It will be as barren as the Moon is today"[73]. The account of possible and likely human futures at 10^2 scale of time is more balanced. Colonization of other worlds – if we ever succeed reaching other solar systems – may make humanity

66 Christian, *Maps of Time*, 22-25 [note 1]; Christian, *Origin Story*, 20-5 [note 64]; Christian, Brown and Benjamin, *Big History*, 14-20 [note 1]; Cynthia Stokes Brown, *Big History: From the Big Bang to the Present* (New York: The New Press, 2007), 4-7.

67 Out of the six requirements specified by Douglas Walton, only two seem problematical, namely consistency ("is the claim in question consistent with what other experts assert?") and evidence ("is expert X's assertion based on solid evidence?"). In the frontiers of cosmology, experts tend to disagree, often wildly so, and evidence is typically circumstantial and strongly theory-laden, often based on mere (other) theories and mathematical models. Douglas Walton, *Informal Logic. A Pragmatic Approach* (Second edition, Cambridge: Cambridge University Press), 217-222.

68 See Unger and Lee Smolin, *The Singular Universe* [note 41], 402.

69 Christian, *Origin Story*, 8 [note 65].

70 Christian, "What is Big History?" 4 [note 62].

71 For a criticism of this reductionist programme by well-known physicists, see R. B. Laughlin & David Pines, "The Theory of Everything," *PNAS* 97, no:1 (2000), 28-31.

72 Christian, *Maps of Time*, 489 [note 1].

73 Christian, *Maps of Time*, 487 [note 1].

less dependent on Earth. Meanwhile, while it is "easy to imagine catastrophic scenarios brought about by nuclear or biological warfare, or ecological disaster, or perhaps even a collision with a large asteroid", also a progressive outcome of history is possible. "It is the in-between scenarios that are both most likely and most difficult to imagine."[74] Even a hesitant commitment to the unfounded cosmic mythologeme of meaninglessness and inevitable end-in-death can easily become counterproductive in relation to the ultimate aims of BH.

Thirdly, at a practical and ideological level, the problem lies in the presumption that in spite of all the specialisation and fragmentation, science is on the side of an enlightened and progressive cosmopolitan vision. In reality science is interwoven with the global problems, both practically (e.g. as part of military-industrial complex or ecologically unsustainable systems of production and consumption) and ideologically (including through the propagation of mythologems that encourage consumerism and competitive behaviour)[75]. To use Thomas Kuhn's terminology, a typical scientist does "normal science", working within a settled – and typically empiricist – framework, leaving the conceptual, social and political framework unchallenged. The results of his or her work can easily be adapted to any technical purpose, including profit- or war-making.[76] This is especially true in a world where the university has been repurposed in terms of success in global competition of corporations and states; usefulness for money-making; and corporate-style efficiency.[77] The repurposing of the university has deepened these problems. According to for example Martin Rees, a British cosmologist and Astronomer Royal, many plausible 21st century catastrophe-scenarios stem from scientific developments. "In the present century the dilemmas and threats will come from biology and computer science, as well as from physics."[78] Among other things, this raises the question whether ethical constraints should be set on science and whether science should be slowed down. An instrumentalist and acquiescent science should not be trusted uncritically, especially under the current political conditions.

Frederick Jameson has remarked that it seems easier nowadays to imagine the end of the world than the end of a particular social system, capitalism.[79] BH appears close to the mainstream also in this regard. Interpretations of recent and contemporary history reinforce constraints on imaginative capacities. The history of the Soviet Union, for instance, suggests "that overthrowing capitalism may be an extremely destructive project" and unlikely to succeed in its own aims (egalitarianism, ecological sustainability). While Christian is truly concerned about rising inequalities and the possibility of ecological destruction, he also assumes that inequalities will remain a problem as long as capitalism remains dominant. Moreover, inequalities can "generate conflicts that guarantee the

74 Christian, *Maps of Time*, 482 [note 1]; Christian, *Origin Story*, 289 [note 65] formulates the same point in perhaps slightly less pessimistic terms and mentions, on 294, also the possibility of emergence of a "new world society that preserves the best of the Good Anthropocene".

75 Cosmic desperation associated with empiricist (positivist) doctrines encourages short-termism and technical-utilitarian orientation to the world, clearly against the point of Big History.

76 In his interesting book, Steve Fuller portrays Kuhn as the official philosopher of the US military-industrial complex. Steve Fuller, *Kuhn vs. Popper: The Struggle for the Soul of Science* (Thriplow: Icon Books, 2006), 32, 123.

77 See for example James H. Mittelman, *Implausible Dream. The World-Class University and Repurposing of Higher Education* (Princeton, NJ: Princeton University Press, 2018); for a vision for the future, see Heikki Patomäki, "Repurposing the University in the 21st Century: Toward a Progressive Global Vision", *Globalizations*, 16 no.5 (2019), 751-762.

78 Rees, *Our Final Century*, 40 [note 26].

79 Fredrik Jameson, *Archaeologies of the Future: The Desire Called Utopia and Other Science Fictions* (London: Verso, 2005), 199. Unlike Christian, for instance Brown does not even mention capitalism in the context of her future-scenarios (although discusses capitalism in the historical part). With regard to the future, she focusses entirely on environmental questions abstracted away from political economy institutions; Brown, *Big History*, 230-46 [note 66].

eventual use of the destructive military technologies now available to us".[80] The hope lies in mitigating some of the consequences of capitalism. Taxes and subsidies can be used to steer economic activities toward more sustainable directions. The living standards of subordinate classes may rise in even the world's poorest countries. Perhaps capitalist peace will prevail in the end.[81] The argument seems to rely, after all, on economic growth.

I am not implying that BH must include a story about the end of capitalism and beginning of something that will replace it. That scenario would mean a commitment to Marxism or some other deep-structure social theory that believes in a compulsive, world-historical sequence of stages of social organization (perhaps following the mythical sequence of Armageddon → Millennium → New Jerusalem), with each stage representing a type of society from a closed list of possible frameworks (such as feudalism, capitalism and socialism).[82] Rather BH should develop its understanding of historical development and change in terms of collective learning, transformative agency, experimentation and concrete utopias[83].

The problem is that currently BH is rather cautious and ambivalent about the needed and desired ethico-political direction. Our current institutional arrangements are not the necessary outcomes of some unspecified organizational, economic, or psychological constraints. Rather new ethical and political are likely to emerge in response to the problems that have emerged because of the acceleration of our cultural evolution. How will the future then turn out? Many key questions are pushed aside or left unanswered. Will production be robotized and automatized entirely; or will production be based on free voluntary association of citizens, perhaps serving purposes we cannot anticipate now? Does money or property continue to exist?[84] How will increasing longevity and our moral learning shape intimate relations?[85] Will the ever-more sophisticated technologies be put in the service of some dystopian purposes or do they open up new possibilities for democratic participation? What about the future of war and violence? If the current trends continue, war and violence will have become virtually absent already in the 2200s, if not sooner.[86] Can nuclear weapons and other weapons of mass destruction be abolished? Will there be any need for people specializing in violence? Will geopolitical states be replaced by a new functionalist system or by world state – or rather, will all states wither away?[87]

80 Christian, *Maps of Time*, 478-81 [note 1].

81 E.g. Erich Weede, "Economic Policy and International Security: Rent-Seeking, Free Trade, and Democratic Peace," *European Journal of International Relations* 1, no:4 (1995), 519-537.

82 For a strong criticism of the 'closed list of possible frameworks' thinking, see Robert Mangabeira Unger, *Politics: The Central Texts: Theory against Fate*, ed. and intro. by Zhiyuan Cui, (London: Verso, 1997), 33-41 *et.passim*.

83 Ernst Bloch introduced the concept of concrete utopia in his *The Principle of Hope* that was published successively in three volumes in 1954, 1955, and 1959. The term has been adopted by various critical theorists. The term *u-topia* is a bit misleading, however, as it means a place nowhere. A positive, hope-inspiring counterpart to dystopia is actually *eutopia*, which could be translated as 'a good place' (or: a place enabling human flourishing).

84 For an example of a serious contemporary proposal to make property conditional, temporary and democratic, see Unger, *Politics*, esp. 306-95 [note 82]. Unger has been an influential politician in Brazil. Also the idea that there is no money resonates with popular imagination, even if unnoticed in mainstream politics. For instance, for a discussion about the ambiguous politics of the post-capitalist Star Trek, see Dan Hassler-Forest, *Science Fiction, Fantasy, and Politics: Transmedia World-Building Beyond Capitalism* (London: Rowman & Littlefield, 2016), 47-66.

85 For some speculations, see e.g. Wagar, *A Short History* [note 61]; James L. Halpern, *The First Immortal: A Novel of the Future* (New York: Random House, 1998).

86 The claim about the declining role of violence is nowadays most often associated with Steven Pinker, *The Better Angels of Our Nature: The Decline of Violence in History and Its Causes* (London: Allen Lane, 2011). About actual and potential countertendencies, see Patomäki, *Disintegrative Tendencies* [note 50].

87 Christian, *Origin Story*, 301 [note 65] mentions this question but does not discuss it. For discussions from a variety of perspectives, see *Cooperation & Conflict* special issue, with intro: Mathias Albert *et al.*, "Introduction: World State Futures," *Cooperation & Conflict* 47, no. 2 (2012), 145-56.

Concrete eutopias establish a direction and normative *telos* to history. At any given world-historical moment, there are some possible rational directions of world history. Over time, there will be a succession of such moments. Setting a direction is a matter of dialectical discussions and debates, always occurring under concrete world-historical circumstances. This is what the openness of world history means. Any claim about rational tendential directionality of world history has to be understood as a dialectical argument within the meaningful human sphere.[88] Rationality cannot be confined to any particular agents or collective category. Once context-specific learning has taken place and a reasonable direction been set, the next logical step is the process of constructing transformative agency. The question of transformative global agency concerns rationality and developments that may take decades. The making of a collective agency is a process of active and reflexive engagement within the world in which we seek to achieve the unity of theory and practice in practice.[89]

Transformative praxis has to be processual, developmental and directional, involving political programmes specifying aims and concrete eutopias. Its organisational forms must be compatible with these requirements. The transformative praxis itself can be transformed on the basis of past experiences and criticism of them. In the globalised world of the 21st century, there is a quest for new forms of agency such as world political party.[90] While a rational direction can be set, debated and disputed, world history is open-ended and, because of our capacity to create something new, unanticipatable. For all imaginable purposes and beyond, humanity's time for its desires and projects can be virtually infinite. World history is just about to begin.

As H.G.Wells put it, according with the spirit of pragmatism, critical realism and visionaries such as Freeman Dyson: "The past is but the beginning of a beginning, and all that is and has been is but the twilight of the dawn". A story portraying the present as "the twilight of the dawn" is more hopeful and inspirational than a gloomy story about us humans marching toward some inevitable end at some scale of time. As Wells proclaimed: "All this world is heavy with the promise of greater things."[91]

Conclusions

In this paper, I have argued that contemporary science is consistent with at least two different storylines. The basic mythologems of contemporary liberal-capitalist societies – verging on cosmic desperation – tend to be in line with market globalism[92]. They are, however, instrumentalist and can easily submit to any demands to provide means for some ends (or be simply indifferent about the use of scientific knowledge). The prevailing narrative is largely and in most time-scales oriented toward a tragic end, thus undermining hope for collective learning and progress. Empiricist science tends to feed into a sense

88 See Heikki Patomäki, "On the Dialectics of Global Governance in the 21st Century: A Polanyian Double Movement?," *Globalizations* 11, no. 5 (2014). 751-68; Patomäki, *Disintegrative Tendencies*, 116-27 [note 50].

89 Roy Bhaskar, *Dialectic: The Pulse of Freedom* (London: Verso, 1993), 8, 158-61.

90 Key questions of a global party-formation include: how would it be possible to combine (i) the capacity to establish an overall, binding direction to the activities of the party with (ii) a democratic process of will-formation that also maximises its learning capacity? Heikki Patomäki, "Towards Global Political Parties," *Ethics & Global Politics* 4 no. 2 (2011), 81-102, freely available at http://www.ethicsandglobalpolitics.net/index.php/egp/article/view/7334; and for a call for such a party, see Heikki Patomäki, "A World Political Party: The Time Has Come", *GTI essay*, February 2019, available at https://www.greattransition.org/ publication/world-political-party.

91 H. G. Wells, *The Discovery of the Future* (New York: B.W. Huebsch, 1913), 60, https://catalog.hathitrust.org/Record/001188090.

92 For the concept of market globalism, see Manfred Steger, *Globalisms: The Great Ideological Struggle of the Twenty-First Century* (3rd ed. Lanham, MD: Rowman & Littlefield, 2009).

of disorientation, division and directionless. Attitudes can vary from indifference to reality to outright scepticism and escapism to fantasy-worlds such as imagined parallel quantum worlds (or sport, soap and nostalgia). Freedom in this mythologeme consists of unimpeded exercise of optimizing behaviour. Consumerism results from the absence of hope and good life.

The alternative storyline, revolving around life and learning and involving cosmic hopefulness, starts from the idea that time, space, causation, emergence and change are real. Cosmos is historical and evolving, and it is also hospitable to life. Over time, life has generated new emergent powers on Earth; it may have done so also elsewhere in the universe. A key point is that emergent cultural layers such as conscious experience, agency, will and intentions are real and causally efficacious. This makes scientific practices and transformative ethico-political activities possible. The rational tendential direction of world-history is grounded in our collective human learning, making it possible to solve problems, absent ills and overcome contradictions by means of collective actions and by building better common institutions.

I have argued above that the storyline of Big History is ambiguous in problematic ways, while not all complexities of our stories are undesirable. Explanations of different outcomes, episodes and processes call for different plots and their combinations. The point is that the life-oriented storyline involves also the possibility of happy endings and new beginnings. It cultivates the idea that the past as we know it may be just the beginning of a beginning. In this epic story involving humankind, the Earth as a whole is now becoming conscious through the gradual rise of human reflexive self-regulation aiming at maintaining sustainable life-friendly biogeochemical, climatic and socio-economic conditions. What is more, reflexive self-regulation may contribute to improving the underlying social conditions of our ethico-political learning. The conditions of free development of any particular human being are social and thus involve deep interconnectedness. Collective learning – shaping reflexively our common planetary conditions and the direction of world history as a whole – can mean, among other things, that the sphere of human freedom is gradually widening. This process of human emancipation can have cosmic significance, also because the expansion of life and culture into space may be a task awaiting humanity.

The Star-Galaxy Era in Terms of Big History and Universal Evolution

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Abstract
The present article attempts at combining Big History potential with the potential of Evolutionary Studies. It does not only analyze the history of the Cosmos. It studies similarities between evolutionary laws, principles, and mechanisms at various levels and phases of Big History. Such an approach opens up some new perspectives for our understanding of evolution and Big History, their driving forces, vectors, and trends; it creates a consolidated field for interdisciplinary research. Of special importance is the point that many principles, patterns, regularities, and rules of evolution, which we tend to find relevant only for the biological and social levels of evolution, may be also applied to the cosmic phase of evolution. This is not so surpris-ing, since the formation, life-cycle and renewal of stars, galaxies, as well as other celestial bodies is the longest evolutionary process that took place in the Universe.

Keywords
Star-Galaxy Era, cosmic phase of Big History, laws of evolution, universal evolutionary principles, Universe, preadaptations, Evolutionary Studies, evolutionary selection, additive and substitutive models of evolu-tion, large-scale structures of Universe, gas-dust clouds, non-uniformity concentration of matter, circulation of matter in the Universe, dark and light matter.

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Introduction

"The effort to understand the Universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy." These words said by the Nobel laureate Steven Weinberg (1977: 155) undoubtedly deserve attention, although they dramatize the origins of interest to the problems of the Universe. In fact, we do not need any justification to explain the desire to understand the origins of all living beings. This aspiration to perceive the world in its entirety lies in the human psyche, it is an integral feature of the mind, at least of a certain kind of people who always want to reach out to ultimate causes (although they can never stop on this way). Moreover, in recent decades the investigation of the world in its entirety (but not of its separate aspects) has been intensified in particular within the Big History.

Big History provides unique opportunities to consider the development of the Universe as a single process, to detect vectors of changes of certain important characteristics of the Universe (such as complexity and energy) at various phases of this development. Some authors analyze important general evolutionary mechanisms and patterns, which can be seen at all phases of Big History (e.g. Christian 2004, 2014; Spier 2010; Baker 2013). However, one should note that the 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 potential with evolutionary approaches can open wider horizons in this respect (see Grinin *et al.* 2011). Indeed, common traits in development, functioning, and interaction can be found in apparently quite different processes and phenomena of Big History. In this respect the universality of evolution is expressed in those real similarities that are detected in many manifestations at all its levels.

This article continues author's attempts to combine Big History potential with the potential of Evolutionary Studies in order to achieve the following goals: 1) to apply the historical narrative principle to the description of the star-galaxy era of the cosmic phase of Big History; 2) to analyze both the cosmic history and similarities and differences between evolutionary laws, principles, and mechanisms at various levels and phases of Big History; 3) to show how cosmic evolution fits the universal evolutionary algorithms and correlates with the common evolutionary laws and patterns. Very few researchers have approached this task in a systemic way. It appears especially important to demonstrate that many evolutionary principles, patterns, regularities, and rules, which we tend to find relevant only for higher levels and main lines of evolution, can be also applied to cosmic evolution. Moreover, almost everything that we know about evolution may be detected in the cosmic history, whereas many of the evolutionary characteristics are already manifested here in a rather clear and salient way. One should also bear in mind that the origin of galaxies, stars, and other 'celestial objects' is the lengthiest evolutionary process among all evolutionary processes in the Universe. Such an approach opens new perspectives for our understanding of evolution and Big History, of their driving forces, vectors, and trends, creating a consolidated field for the multidisciplinary research.

While studying the issue it became clear that the number of similarities and common features of the evolutionary progress at its various stages and levels is extremely large, that they can be revealed in the most seemingly different processes and phenomena. Almost everything, that we know about evolution can be already found at its cosmic phase (see also Grinin 2013, 2014a, 2014b, 2015a, 2015b, 2017, 2018, 2019). Naturally, many phenomena are revealed in a rudimentary or unsystematic form, but a number of characteristics, on the contrary, are more clearly expressed just at the cosmic phase. And at the same time, when characteristics and features of biological or social evolution unexpectedly reveal their roots or early forms in earlier phases, it becomes clear that the universality of evolution is a reality found in many manifestations.

Our world is immensely diverse and unlimited in its manifestations. However, fundamentally it is a single world – that is why it is so important to study those fundamentals.

I. THE FORMATION OF THE LARGE-SCALE STRUCTURE OF THE UNIVERSE

Preconditions. After the Big Bang, our Universe 'lived' for quite a long period of time without any stars, galaxies, clusters, and superclusters of galaxies (Khvan 2008: 302)[1]. The formation of modern structure of the Universe lasted for billions of years. However, the first stars and galaxies turn out to have emerged not later than 200–400 million years after the Big Bang (*e.g.,* see European Commission 2011). We are going to discuss this in detail in what follows. And what was the matter from which they had emerged?

Approximately 270,000 years after the Big Bang, a large phase transition occurred resulting in the emergence of matter in the form of atoms of hydrogen and helium. Later, they started to consolidate in new structures (see below). The main mass of this matter concentrated in gas-dust clouds that could have tremendous sizes (dozens parsecs, or even more).[2]

1 See Gorbunov and Rubakov 2012; Guth 1997: Guth A. 2002; Guth 2004; Wood 2018; Grinin 2018 about the Big Bang and the theoretical problems associated with it.

2 1 parsec ≈ 31 trillion km.

Nowadays one can speak about such cosmic fractions as inter-stellar gas and cosmic dust. They can be found either in a very rarefied state or in the form of clouds. But it is known that the clouds we currently observed consist of gas and dust mostly in equal proportions. Therefore, one usually speaks of gas and dust clouds.

For the first time we observe Nature in the role of a constructor. Before that, it had formed just the basic elements. Now one could observe the emergence of enormous structures from tiny particles and 'specks of dust'. After that one could observe this constantly: *large-scale structures are composed of myriad minute particles and grains.*

The seed grains needed for structuring. The formation of clouds (and later stars and galaxies) meant a concentration of matter on enormous scale, which could have been caused only by gravity. However, this only force is insufficient for structuring, because in 'an absolutely homogenous universe the emergence of large-scale structures (galaxies and their clusters) is impossible' (Dolgov *et al.* 1998: 12–13). Thus, certain seed grains are necessary – this is comparable with formation of rain drops that emerge around particles of dust or soot; or with formation of a pearl around grit.

Small fluctuations are often needed for the powerful forces to start working. Actually, minor fluctuations (minute deviations from homogeneity) occurred in the Universe early on. Then the larger fluctuations happened. They could act as seed grains for the formation of galaxies and the matter concentrated around them on a much larger scale until the quantity started to transform into a new quality. However, it is not clear what kind of fluctuations caused the formation of galaxies and what is the mechanism of their formation. The initial fluctuations in other evolutionary spheres also often remain a mystery.

This is a perfect example of the point that *the non-uniformity (in particular with respect to the distribution of matter, energy, etc.) is a universal characteristic*. Any major evolutionary shift in biological and social systems is preceded by the concentration of certain forms, resources and conditions in certain niches and places. The higher the stage of evolution is the more significant this process is. Thus, in the major system the common processes may proceed in their usual way, whereas in the concentration zone some peculiar processes start (this is what takes place in star formation zones).

Thus, we might formulate *an evolutionary rule of important heterogeneity and fluctuations*. The emergence of critical heterogeneity which can be the core of changes is often required for the evolutionary change (even within the frameworks of a typical transformation without qualitative evolutionary growth). An absolute homogeneity makes some evolutionary processes impossible while even a slightest difference can trigger the regrouping of matter or elements in the assemblage. And a new structure and order arise on this basis (see Grinin 2017, 2018 for more details).

The epoch of formation of the large-scale structures in the Universe. The first galaxies and stars

Dark and light matter. Nowadays it is generally accepted that dark matter plays an important role in the formation of the first galaxies, as it appeared capable of consolidating into clusters much earlier than the light (baryon) matter. The latter could not contract until the end of the hydrogen recombination (atom formation) due to radiation (270,000 years after the Big Bang). Only when hydrogen nuclei and electrons were able to merge and form atoms, whereas photons separated from the matter and flew away, the pressure of the radiation dramatically dropped. Perhaps, we observe here a very interesting evolutionary pattern of a transition from disorder to order and decreasing entropy. This case correlates rather well to Herbert Spencer's universal principle of evolution (Spencer 1862: 495, 1970: 396)[3]. He formulated it as a law

3 It is interesting that he gives an example connected with the Solar system. "If the Solar System once existed in a state of indefinite, incoherent homogeneity, and has progressed to its present state of definite, coherent heterogeneity; then the Motion,

of the transition of a substance during its qualitative development from indefinite (non-differentiated and non-specialized) homogeneity to definite (more specialized) heterogeneity. As a result, the light matter would fall in potential holes prepared for it by the dark matter. Though the dark matter was initially more capable to structuring than the light matter, the progress toward structuring turned out to be very short and leading to almost a dead-lock.[4] Meanwhile, the evolutionary potential of the light matter was based on the 'achievements of the dark matter'. Such a model of development is rather typical for evolution. For example, long before the transition to agriculture some gatherers of cereal plants invented many things (sickles, granaries, and grinding stones) that later turned to be rather useful for agriculturalists, whereas specialized hunter-gatherers turned out to be an evolutionary dead end.

The epoch of formation of the large-scale structure of the Universe. First galaxies and stars. There are rather diverse opinions on timing, process characteristics and sequence of formation of stars, galaxies, galaxy clusters and superclusters. There is a hypothesis that galaxy protoclusters were first to originate. According to it the same process that engendered galaxy could operate on a larger scale, and the first generation of gas clouds being protoclusters, that fragmented to form galaxies (Peebles 1980). Similar phenomena can be found at higher levels of evolution, when something general is formed (which will later turn into a larger taxon in the hierarchy), that later differentiates into lowest-order taxa. That is how species and classes are formed in biology. The same refers to a society: at first there emerge rather large formations, like families of languages and then the languages, ethnic super-groups and then ethnic groups, and sometimes early large empires or states; and afterwards within their framework statehood goes one or two levels down. In other words, there emerges a non-differentiated large structure which is capable to produce a great number of peculiar structures.

However, a more commonly held hypothesis suggests that protogalaxies (in the form of giant condensed gas clouds) were the first to emerge within the structure of the Universe, and later they became the birthplace for separate stars and other structural elements (see, *e.g.*, Gorbunov and Rubakov 2011).

However, in recent years new evidence has come to hand to support the idea that those were the stars that appeared first. This discovery somehow modified the previous theories. At present, it is widely accepted that the stars were first to emerge, but those were the giant stars, much more massive than most of the later-formed ones (May *et al.* 2008). Because of the absence of carbon, oxygen and other elements that absorb the energy from condensing clouds, the process proceeded more slowly in that epoch; thus, only giant clouds could condense producing massive stars hundreds times larger than the Sun (*Ibid.*). Nowadays we can also find such giants which have 100–200 solar masses, but they are considered to be unstable (see Surdin, Lamzin 1992). Such giant stars lived only a few million years (the larger is star, the shorter is its life). In addition, the first stars contained a small amount of heavy elements. Thus, more than one generation of stars could change, until the quantity of heavy elements gradually increased. The emergence of 'heavy elements' from the 'dead star stellar remnants' resembles the formation of marine sediments or fertile soil at the Earth's surface from the accretion of skeletons or conversion of remnants of dead plants. The circulation of matter in the Universe is always observed everywhere and at all levels.

In recent years we have witnessed the discovery of a few galaxies that are claimed to be the oldest in the Universe. Meanwhile, the dates of formation of the first galaxies are shifted closer and closer to the Big

Heat, and Light now exhibited by its members, are interpretable as the correlatives of pre-existing forces; and between them and their antecedents we may discern relations that are not only qualitative, but also rudely quantitative.

4 However, as with any evolutionary dead end, this does not mean an absolute stagnation. At present, in galaxy halos the dark matter is structured in certain smaller structures (see, *e.g.*, Diemand *et al.* 2008).

Bang. The emergence of the first galaxies is dated to less than 400 million years after the Big Bang; and there are even claims that some more ancient galaxies have been discovered. They are claimed to have emerged only 200 million years after the Big Bang (see European Commission 2011). The evidence on the first stars refers to *c.* 150–200 million years after the Big Bang – hence, stars and galaxies appear to have emerged almost simultaneously. Since that time the substance in the Universe coexists in three major forms, depending on its density: in a dense state in celestial bodies, in a rarefied form in clouds of different sizes, and in a highly rarefied state (dozens of times if compared to clouds) in interstellar gas.

Thus, galaxies were actively formed during the first 300–400 million years after the Big Bang. However, although some structures emerge already at that time, still they were not yet dominant in the Universe, and they were still very amorphous and crumbly (Hawking 1998). The formation of a more or less stable large-scale structure took some time, probably a couple of billion years. As we mentioned above, the formation of a number of heavy elements without which the creation of resilient stars was impossible also took time. The formation of the Universe close to the modern structure could hardly take place quickly.

II. THE ERA OF THE STAR-GALAXY STRUCTURE OF THE UNIVERSE

The whole history of the star-galaxy phase of cosmic evolution is basically the history of formation of various structures of different size, as well as their merging into larger structures (but it is a history of their disintegration as well). The formation of galaxies and their clusters, as well as of stars and other celestial bodies was the longest evolutionary process that had ever taken place in the Universe. At present we observe that this process is still going on alongside changes and disappearance of galaxies and stars. During the first eight billions years, the formation of huge diversity of stellar bodies and new heavy elements took place in the Universe until about 5–4.5 billion years ago there the conditions were formed for the formation of stellar (Solar) system. On one of its planets there started new geological, chemical and biochemical processes (for more detail see Christian 2004; Lin 2008; Batygin et al. 2016; Grinin 2017, 2018).

1. The structure of the Universe

1.1. Evolutionary principles of the structure of the Universe. The formation of galaxies and their clusters was probably the process that lasted for billions of years. Some principles describing the basic structure of the Universe may be applied to different levels of evolution (below we will consider just two of them).

1) *The combination of antagonistic qualities.* For example, in the structure of the Universe one can find the combination of uniformity and non-uniformity. The uniformity is already manifested at the inflation phase, when the Universe started inflating evenly in all dimensions. The uniformity has preserved till present, but only at the largest scale (of an order of magnitude of 100 megaparsecs[3]). For reference, the size of the largest galaxy clusters (such as our Local Group with the center in the Virgo constellation) is 40 megaparsecs at most (Gorbunov and Rubakov 2011). The non-uniformity of the Universe is manifested at scales smaller than 100 megaparsecs; and the smaller is the scale, the more salient is the unevenness. The combination of antagonistic qualities is a phenomenon that is rather characteristic for many other evolutionary levels. Thus, the antagonistic notions like 'even surface' and 'uneven surface' are quite applicable to the Earth surface: at bird's eye it looks even.

2) *Density and sparsity can be traced everywhere,* starting from the atomic structure, where the mass is concentrated in a tiny nucleus, while most of the atom is an empty space. There is a huge non-uniformity between the scale of the Universe and the space that the main mass of the light matter occupies within it (at least, baryonic) matter. It is concentrated, first of all, in stars which actually occupy only a 10^{-25} part of the total volume of the Universe (not taking into account the galaxy nuclei [Pavlov 2011: 43]). Were there such proportions in the ancient Universe? Probably,

not. Therefore, the concentration of the matter is increasing. Not only the hard matter is distributed very unevenly throughout the Universe; the same is true of the gas. Much of this gas is concentrated in giant molecular clouds which are of many thousands of solar masses (Lipunov 2008: 37).

At the same time the difference in density is fractal, which is especially evident in the high-density zones. The factors contributing to such unevenness are not always clear; for example, it is not clear, what the uneven distribution of masses during the formation of galaxies (Weinberg 1977) as well as many other processes of distribution, concentration and dissipation are connected with.

But the principles of uneven distribution of the matter mass at different evolutionary levels are rather similar. For example, at present the main mass of the Earth's population is concentrated in a rather small territory in comparison with the total territory where life on the Earth is possible.

1.2. The structure of the contemporary Universe

The main structural elements of the Universe are galaxies, their clusters, and superclusters. Superclusters basically form our Metagalaxy[5]. All the structural elements are rather stable in terms of gravitation, though they can split, merge, and collide.

Galaxies are integral structural entities with a rather complex structure which includes, in addition to regions and arms, a nucleus (core), semi-periphery (so called 'disc'), and periphery (so called 'halo') (Baade 2002: 255). The halo consists of both single stars and various stellar clusters. The halo's radius (a few hundred thousand light years) is much larger than the radius of the galaxy's disc.[6]

According to Hubble, the galaxies are classified into spiral, elliptical, and irregular with various subtypes (*Ibid*.: 18–32); yet, by now one more galaxy type has been identified – the lenticular galaxies.

> A galaxy contains around 100 to 200 billion stars. There are small (dwarf) galaxies with a few million stars, there are also giant galaxies consisting of up to a trillion stars. Our galaxy with its mass of about 10^{11} solar masses is one of the largest ones. It contains 200–300 or even more billions of stars. However, the mass of our neighbor – the Great Andromeda Nebula (M31, found in our cluster of galaxies (the Local Group) – is about three times larger. Probably, the most famous M87, which is situated in the central part of the cluster of galaxies in Virgo constellation, has the largest mass. Apparently, the mass of this Galaxy exceeds by hundreds times the mass of our Galaxy. At the other pole there are dwarf galaxies whose masses are ~ 10^7 of solar mass, that is several dozens of times more than the mass of globular cluster (Shklovskii 1978: Part 1, Chapter 6).

Stars are distributed rather unevenly throughout galaxies, stars are parts of various groups and clusters; some of them consist of just a few stars, but some clusters can contain a few million stars. For example, within our Galaxy more than 1,500 star clusters have been identified (Surdin 2001). There are many globular clusters – spherical clusters tightly bound by gravity and consisting of hundreds of thousands, as a rule, rather old stars. These are old stars (there are 150–200 in our galaxy). There are about 22 per cent among our nearest galaxies. In these galaxies, a bright main flattened body, 'a lens', is surrounded by a weak halo. Sometimes the lens is surrounded by the ring (see: Novikov 1979: ch. 1, § 8). More than half of the members of the Local Group are the older elliptical galaxies with intermediate or minor

5 If, according to some researchers, the Metagalaxy is not the only one in the Universe, then for some time it will be considered as the largest structural unit of the Universe (see Pavlov 2011: 52). If the Universe is not a Universum but a so-called Multiverse, then the Universes or their groups will be the maximum unit of the structure (see Vilenkin 2006; 2010).

6 There might be an invisible halo consisting of dark matter behind the visible halo. It may be found in many (if not all) galaxies, whereby the diameter of the dark halo might exceed the diameter of the visible halo by an order of magnitude (see Ryabov *et al.* 2008: 1131).

luminosity (Novikov 1979: 31). Galaxies are complex and (to a considerable extent) self-regulating systems, within which some stars disintegrate, whereas new stars form from cosmic gas and dust. The circulation (which results in processes of renovation of matter and its mixing) takes place at all levels of the Universe – both spatially and at different levels of evolutional complexity.

An average galaxy cluster consists of 500–1000 galaxies. Galaxy clusters have a rather regular structure which is likely to include a massive nucleus in the center. Galaxy superclusters are entities consisting of 2–20 galaxy clusters and galaxy groups as well as of isolated galaxies. In general, there are known more than 20 superclusters, including our Local Group (Gorbunov, Rubakov 2012: 4).

1.3. Generations of galaxies and stars

There are rather diverse opinions on the number of generations throughout the evolution of the Universe. In addition, there is no consensus on which galaxies should be regarded as old, and which galaxies should be considered young. The point is that within a single galaxy one can find stars and their aggregates that considerably differ in their type, age, and other parameters. For example, the age of our Milky Way galaxy is more than 12 billion years, but that is the age of just its halo while many stars in its branches are only two-five billion years or less. Yet, it appears possible to single out a few widely accepted basic ideas.

1) In the evolution of the Universe, there have been three (or at least two) generations of galaxies and stars. In general, old galaxies are smaller and dimmer. Their stars contain dozens of times smaller quantities of heavy elements than the Sun. The astronomers can hardly observe any star formation processes within such galaxies. There is also a hypothesis that more dark mass is concentrated in old galaxies in comparison with younger ones. The same way, older and younger stars differ from each other in their size, luminosity, and chemical composition.

2) It is difficult to speak about a clear periodization of generations of galaxies, because of the ongoing process of formation of galaxies and stars. Galaxies need to constantly renew their composition in order to retain their identity. As Iosif Shklovskii maintains, in this respect galaxies are very similar to primary forests with its mix of tree ages (whereas the age of trees is much less than the age of the forest itself [Shklovskii 1978]). The motility and variability of the celestial landscape resembles very much the motility of geological landscapes.

3) The formation of galaxies can proceed in different ways, for example, through the absorption of smaller galaxies by the larger ones in particular as a result of a collision. If a small galaxy comes into collision with a massive one, it is absorbed by the latter and loses its identity. Every time when passing near a massive galaxy the stars estrange from it (May et al. 2008). In this case both young and old clusters and groupings of stars are combined (see about it below). Another way is merging. Galaxies of younger generations can sometimes form through the accretion of a few small, weak and compact galaxies into a single galaxy. In this case they became 'building blocks' for galaxies. Finally, it may happen that two large galaxies collide. Such a collision may take billions of years and be accompanied with active star formation and emergence of very large and bright stars. The latter means that these are short-living stars, that is there will be many bursts of nova and supernova. Finally, galaxies may diverge again, but in this case they turn out to be very different from what they used to be before the collision, whereas one more galaxy may emerge out of the matter estranged from the both galaxies (see May *et al.* 2008: 142).

There are numerous analogies to those models of galaxy formation in biological, geological, and, especially, social evolution. As stars and galaxies are composed of more or less homogenous matter (that can be divided or united rather easily), they somehow paradoxically resemble societies that consist of people who can be included into other societies through integration or capture. On the other hand, captures are also attested among social animals (*e.g*., among ants see Genet 2007).

4) Galaxies are collections of different types of stars. However, there are certain peculiarities as regards the position of old and young stars within galaxies which is probably connected with the self-regulation within the galactic systems or the peculiarities of star formation which occurs in large groups, or due to other factors (about self-regulation in cosmic world see Grinin A. 2016). Thus, within our galaxy the younger stars (such as the Sun which is a few billion years old) are generally larger, hotter and brighter. They are located toward the disc plane, and, especially, within the galaxy arms; whereas in the galaxy periphery (in its halo) one would find older stars more than 12 billion years old (which suggests the overall age of our galaxy). Yet, older and younger stars may be also located rather close to each other. Thus, one may find many old stars near the galaxy center (bulge), but there are also young stars that emerged from the matter produced by the disintegration of older stars. The highest stellar density is found in the galaxy center where it reaches a few stars per cubic parsec.

As we already mentioned, the very old, not bright, not hot and not massive stars contain many times less amounts of heavy elements than the Sun. It is not surprising that these stars and young, hot, and bright stars of the surface of disc, arms and halo were labeled differently as 'Population I' and 'Population II' respectively.[7] It is generally accepted that the majority of globular clusters are very old (12 billion years old or even more). But the dispersed or open galactic clusters are dozens or even hundred times younger than globular clusters (*i.e.* they are just hundreds of millions of years). But there are younger stellar associations (see, *e.g*., Surdin and Lamzin 1992; Surdin 2001).

On the one hand, the preservation of generations of stars and galaxies demonstrates an additive character of the evolution of abiotic systems, whereas we can see elements of substitutive model of evolution at biological phase and its full system at social phase of Big History. However, the capture of stars and galaxies with their subsequent integration and prolonged processes of collision of galaxies demonstrates that in abiotic natural systems one may still find some other models of evolution – connected with 'wars' and 'submission of outsiders'.

The type of development through the emergence of different generations of individuals and species (preserving certain genetic features, on the one hand, and accumulating important changes in their structure and characteristics, on the other) is rather widespread at all phases and levels of universal evolution. Within any biological class or order (*e.g.,* perissodactyls) we can see how important characteristics vary and gradually change from one species to another, whereas due to those characteristics some species press out others and occupy better niches (see, *e.g*., Grinin, Markov, and Korotayev 2008). Various types of states and civilizations also rather vividly illustrate the progress: for example, more organized and developed states emerge through the absorption of the achievements of less developed generations of states, which one can illustrate using examples from the history of Ancient Rome, Byzantium, some Medieval European states and so on. The coexistence of different generations sometimes leads to the situation when younger and more advanced entities either transform the older ones or form a symbiosis with them (though in some places one may find 'restrictions' for older types and generations).

1.4. Change of the chemical composition of the Universe

Hydrogen has always been the most abundant element in the Universe chemical composition; yet, its share constantly decreased. This occurred (and occurs) because hydrogen is the main fuel for the nuclear fusion reactions that support life and luminosity of stars. Despite the tremendous amounts of energy

7 Note, that when there appeared an evidence of the existence of the stars of the first generation which emerged at the age of the Universe of 150 million years from the moment of the Big Bang (see about it above), they were named 'Population III' in order to follow the conventional designation.

released during these reactions, the energy release rate is very low. For example, the intensity of the solar radiation is 2 erg/g·s, which is almost equal with a pile of burning leaves. Stars shine brightly because they are massive and large (Surkova 2005: 9).

Increasing temperatures inside the core of some stars were needed for the formation of new elements that were absent in the era of recombination. However, all of the fusion reactions that occur to produce elements larger than iron no longer release energy. Reactions of another type are needed for the formation of elements heavier than iron – those reactions consume more energy than release. That is why there are such relatively small amounts of heavy elements in the Universe. Yet, such peculiar reactions do take place – for example, in neutron stars and during explosions of supernovas. In supernovas, during their bursts, within about just 100 seconds heavy elements from the end of Mendeleev's periodic table are formed, including uranium and thorium (Surkova 2005: 9).

When supernovae explode, heavy elements are expelled through the Universe with stellar winds and through the fall of the dispersed matter on the surface of cosmic bodies (so-called accretion). As stars turn to be the main centers of the synthesis of chemical elements, the distribution of heavy elements in the Universe is very inhomogeneous.

The emergence of heavy elements and their concentration in certain bodies and compositions are extremely important processes, which lead to an enormous increase in the number of matter combinations, and consequently have an evolutionary potential; in particular, they lead to the start of the full-scale chemical, biochemical, and biological processes. In certain respects, such a slow and uneven accumulation of new structural elements (heavy elements) resembles the process of an accumulation of valuable mutations in biological evolution, or the accumulation of valuable innovations in social evolution (all of them bring the expansion of the evolutionary potential and increase the rates of evolutionary changes).

The similarities and differences of stellar compositions (the presence of heavy elements) somewhere resemble similarities and differences in genome. All living organisms mostly have its similar structure and all huge differences are caused by small divergences (by several percent) in genes.

2. The Evolution of Galaxies and Stars

2.1. Processes of the formation of galaxies and stars

Until quite recently, the processes of star formation were entirely concealed from an external observer; however, at present due to the technological progress one can observe some aspects of those processes in many parts of our galaxy. Those observations confirm the theory of stellar formation from cold clusters that are heated by gravitation and pressure.

Briefly, this process may be described as follows. Within giant hydrogen and helium clouds, some heterogeneities emerge, which launch (under certain conditions) the gravitation processes that start to collect that mass into spherical forms. Sometimes a direct formation of a giant mass of gas clouds takes place, from which a galaxy or a star cluster later emerges. In this case the cloud fragmentation may occur and thus, more and more gas-cloud spheres (there could be hundreds of millions, or even hundreds of billions of them) emerge, which can gradually transform into protostars. This process continues up to the point when the gas density becomes so high that each new fragment already has a mass of a star (Surkova 2005: 49). Then the gravity starts impeding further fragmentation. This process is denoted as 'cascade fragmentation'. It is remarkable that it resembles certain processes in social evolution – for example, the fragmentation of large early states into separate parts that decentralize up to the point when further division becomes unreasonable (*e.g.*, in certain periods there were dozens and hundreds of independent states in the territories of Germany or France).

As enormous gas/dust clouds appear unstable, they disintegrate into large bundles, so the formation of stars proceeds in groups. This phenomenon is of interest not only with respect to stellar evolution. The group formation is rather typical for evolution in general (in this way populations and sometimes new species emerge; chiefdoms, city-states, and sometimes political parties emerge in groups, and so on).

The further process of the star formation is connected with the point that the initial compression heated the gas to a rather high temperature that, on the one hand, prevents the further compression of the gas, and, on the other hand, eventually contributes to the onset of the nuclear fusion reaction (Hawking 1998).

2.2. Diversity of stars and galaxies

Diversity is an absolutely required condition of evolutionary development. And this condition is fully realized within cosmic evolution. As has been mentioned above, galaxies differ in their types, age, size, and structure. They also differ in many other characteristics including the chemical composition and the immediate system to which they belong, for example whether they are binary or isolated stars, whether the stars have a planetary system or not, *etc.* Those differences may vary greatly.

The varying impact of gravitation and resulting peculiar behavior of gas-cloud masses could become the reason of formation of different types of galaxies. That means that galaxies are born either as spiral or elliptic ones and the type of galaxy is preserved in the course of its evolution. In particular, a galactic structure is to a large degree determined by the initial conditions of its formation (*e.g.*, by the character of rotation of the original gas clump from which a galaxy is formed).

Stars differ in mass, temperature, chemical composition, luminosity, age, and other characteristics. Those differences may vary greatly. For example, with respect to masses, stars range in mass from about 0.1 to 100 or more solar masses. There are some considerations that the thermonuclear fusions cannot go in a star with the mass of less than 8 % of the Solar mass that is why such objects are not attributed to stars. It is rather natural that the number of smaller entities is orders of magnitude larger;[8] actually, the same phenomenon may be observed, for example, in Zoology or Political Geography where the number of small animals or countries is much larger than that of large ones.

2.3. The life-cycle of a star: Stages of stellar birth, aging, and death

Protostars. As mentioned above, stars emerge through the condensation and compression of gas clouds under the influence of gravitational forces. This is a protostar phase. In comparison with the subsequent life of a star, the period of its slow contraction seems rather short; however, actually this is not a quick process as it continues sometimes up to 50 million years (Surkova 2005: 50). During this period of time, there is a tremendous rise in the temperature at the core of the protostar, the temperature may grow up to 8–10 million Kelvin, and, as a result, thermonuclear reactions become possible. The protostar becomes a young star. However, an external observer will only be able to see it in a few hundred thousand (or even a few million) years when the cocoon of gas and dust surrounding the protostar dissipates.

Actually, we deal with a sort of miracle – a giant shining incandescent body, which is capable of living for billions of years, emerges from an absolutely amorphous, lacking any structure, opaque, and cold mass of gas mist. In other words, we deal here with a vivid example of self-organization that takes place under the influence of gravitation and thermodynamic laws. In particular, an intensive contraction leads to heating, which increases the internal pressure, which, eventually, stops the compression process (for more details about the processes of young stars emergence including the direct observation of them as well as about the Sun's birth see Marakushev et al. 2013; Marov et al. 2013; Grinin 2017, 2018).

One may also note that the emergence of stars and galaxies must have a certain trigger that creates turbulence and heterogeneity. Those triggers and catalyzers are the inherent components of evolutionary

8 Thus, for every ten million red dwarfs we find only 1,000 giants and one supergiant (Surkova 2005: 26).

mechanisms that may be found in many processes: in chemical and geological processes, within biological evolution with respect to fast formation of species, or within social evolution with respect to state formation (see Grinin 2011 for more details). The supernova shock wave, the collision of a molecular cloud with spiral arms of a galaxy and other events can become such a trigger of the star formation (Surkova 2005: 50).

Another (the longest) macrophase is the main sequence star. During this phase of the stellar lifetime, nuclear-fusion reactions that burn hydrogen to helium in the core, keep the star shining. That is why the duration of the main sequence phase depends mainly on the stellar mass. The more massive is the star, the shorter its lifespan on the main sequence (as with a larger mass the 'fuel combustion' processes run more intensively). A star preserves its size and form due to the mutual struggle of two forces: the gravity that tries to compress the star and the gas pressure produced as a result of nuclear reactions and powerful heating. There is a dynamic equilibrium between temperature and gas pressure. With growing temperature, the gas expands and works against the gravitation forces, which results in cooling of the star; this way the thermal balance is kept. In the lifetime of stars and galaxies, as well as at all other levels of evolution, we find numerous cases and different forms of the interaction between two opposite processes which make it possible for 'individuals' to live. The processes of assimilation and dissimilation support vital activities within biological organisms; the processes of animal reproduction and their extermination by predators support the population balance; interaction between processes of production and consumption is the basis of the reproduction of social systems, and so on.

Red giants. The new phase of stellar evolution is connected with the exhaustion of hydrogen supplies. The gas pressure (that maintained the star balance when necessary fuel was available) decreases and the stellar core compresses. This leads to a new increase in temperature. A star starts to burn heavier elements and thus, the stellar composition significantly changes. Simultaneously with the compression of the core, the star's outer layers expand (they can even detach to form a gaseous nebula). In general, the star inflates and expands a few hundred times, and it transforms into a red giant, and then with further expansion – into a red supergiant (large stars with more than ten solar masses transform directly into supergiants). This phase lasts for about one tenth of the 'active lifetime' of a star, when the processes of nuclear fusion go on in its depths.

Star death: three cases. The next phase is the transformation of a red giant or supergiant. Actually, the new form depends on stellar mass and a number of other characteristics such as the stellar rotation and velocity, the degree of its magnetization, and so on. The following three outcomes are considered most typical. They depend on stellar mass (but the limit value estimates vary significantly, and so below I will mention the main alternative values after the slash).[9] Stars with the masses smaller than 1.2–1.4/3 solar masses transform from red giants into the so-called 'white dwarfs', when the star sheds its outer envelope to form a planetary nebula with an extremely contracted core (down to the size of the Earth). The further compression does not occur because of the so-called degenerate electron gas pressure that does not depend on temperature. As a result, the white dwarf is rather stable. However, due to the lack of hydrogen and helium, thermonuclear fusions can no longer proceed within such a star. A white dwarf is very hot when it is formed; yet, afterwards the star cools and transforms into a 'black dwarf', that is, it becomes a cold dead cosmic body.

For stars with an initial mass of more than 1.2–1.4, but less than 2.4–3 (in another calculations from 3 to 7–10) solar masses, their slow and gradual aging results

9 According to one of classifications (that might be more correct than the one reproduced below), it appears possible to subdivide all the stars just in two classes: a) massive stars (with a mass exceeding *c.* 10 solar masses), producing neutron stars and black holes, and b) non-massive ones producing white dwarfs (Lipunov 2008: 99).

in an 'infarct', that is a collapse. After the depletion of hydrogen and the decrease of the internal gas pressure (that used to balance the gravity), under the influence of gravity the core gets extremely compressed (by dozens thousand times – up to the radius of ten kilometers) just in less than a second. Almost simultaneously the external layers of the star are blown away with a huge speed as a result of shock wave. This supernova shines brighter than millions of ordinary stars, but for a very short period of time. This explosion expels the stellar material into interstellar medium and thus, there occurs the formation of considerable quantities of heavy (heavier than iron) elements that afterwards concentrate in various celestial bodies. The remaining core contracts to become a neutron star (which is supposed to contain super dense neutron fluid) In its size, such a star is 5 billion times smaller than the Sun, but it is hundreds of thousands of times brighter because the temperature on its surface is 1000–1500 times higher than on the Sun (Lipunov 2008: 133).

If stellar mass exceeds the limit of 3/7–10 solar masses, after hydrogen is burnt out it will start collapsing and explode (though sometimes it may collapse without an explosion), but the force of compression will be unlimited, as the gravity becomes enormous because of the huge mass and absence of internal forces that can prevent the collapse. The action of the gravitational force which is balanced by nothing leads to the situation when the stellar diameter becomes infinitesimally small. According to theoretical calculations, the star is transformed into a black hole whose gravity fields are strong for light to escape.

III. UNIVERSAL EVOLUTIONARY PRINCIPLES IN THE STAR-GALAXY ERA

1. Life, Death, and Catastrophes in the Evolutionary Aspect

The irreversible character of evolution is its most important characteristic. It can be observed as a steady movement to more complex structures and forms of organization, to changing chemical composition of the Universe, *etc.* As regards the individual objects, the irreversible character of evolution is obvious and undoubted. A star which passed through a certain phase of life cannot reenter this phase.

The stellar lifetime in terms of maintaining and breaking the dynamic equilibrium. At the initial phase a cloud of gas 'burns' itself under the compression like packed straw or rags ignite spontaneously. The next phase of self-organization is connected with the formation of complex stellar structure on the main sequence phase during which burning out of hydrogen occurs. After burning out of the most part of hydrogen a star enters a new phase, it expands and transforms into a red giant. At the same time the processes of self-organization start again and the stellar structure radically changes (highly compressed core coexists with the expanded envelopes). After the fuel is burnt out in a red giant, the next phase is compression under the influence of the gravitational force and formation of a brand-new structure: small but very massive core with extremely high density of the matter within it.

Let us consider the stellar life in terms of maintaining and breaking the equilibrium. First of all, there is a thermal equilibrium, when the rate of energy produced in the core (through thermonuclear fusions) balances the loss of energy through the emission of radiation into space. This equilibrium is broken when hydrogen fuel is gone. The reserves are apparently compensated when a star starts using another type of energy. This may occur through the contraction of the star which begins fusing helium into carbon, thus producing many times more energy for every atom; afterwards heavier elements may be used as fuel, and each heavier element will produce more and more energy per atom. Meanwhile, the core of the star begins to increase in temperature. There is equilibrium in terms of pressure of different forces and preservation of a certain form and size of the star. Within the main sequence phase, the balance is maintained as the gravity pulls all the stellar matter inward, toward the core, while gas pressure pushes heat and light away from the center.

This pressure exists until the reserves of nuclear fuel are exhausted (Efremov 2003: 97). With respect to red giants one may speak about equilibrium of another kind in two dimensions. In the core the temperature grows due to contraction and thermonuclear reactions of higher levels (described above) start; as a result of those reactions the temperature may grow up to 100 million Kelvin. That is why a stronger gravity is balanced by a stronger (due to temperature) gas pressure. In the meantime, within the shell the equilibrium is achieved through the multifold expansion of the outer layers. In neutron stars and white dwarfs, the subsequent phases of the stellar lifetime, there is their peculiar equilibrium.

The problem of the individual's death. Death as an opportunity for life to go on. Stellar life and death can hardly leave anybody indifferent. Actually, within the Big History framework, this is the first time when we come across the problem of a life cycle of individual objects in such an explicitly expressed form. On the one hand, the star's fate, lifespan, and type of death depend on initial parameters, as if they were 'genetically programmed' (and, hence, they may be forecasted); on the other hand, they may be altered by some contingencies. Thus, the star's fate is not 'fatal', indeed. Binary star systems increase highly the variability of the individual star fates; as Lipunov (2008: 252) puts it, we deal here with a kind of 'quadratic evolution'. What is more, it is actually possible to speak about differences in the 'individual' stellar behavior or 'within a group', because the interaction of two, three, and more stars may lead to very significant differences and unusual results that cannot emerge within the development trajectory of individual stars. In fact, similar patterns are observed at other levels of evolution, when behavior of pairs or groups of individuals produces outcomes radically different from the ones observed with respect to the behavior of an individual not interacting with others.

Finally, the meaning of individual's death for evolution may be different. Up to a certain degree one may observe a direct correlation between the 'strength' of death, the power of the stellar explosion, and the formation of conditions for a new evolutionary search. Stellar explosions affect the dynamics of their environment; consequently, they may help create unusual conditions that contribute to the emergence of certain developmental deviations. Within tens of thousands years the zone of explosion expands to a vast area of interstellar medium (covering the distances of dozens of parsecs); in this area one can see the formation of new physical conditions (in particular, temperature, density of cosmic rays and magnetic fields strength). Such a disturbance enriches the respective zone with cosmic rays and brings changes to chemical composition (Shklovskii 1978). The explosions also contribute to star formation. Thus, a star does not die in vain. One can draw here an interesting analogy with extinctions in biological evolution which contribute to new directions of speciation. The stellar destruction can be also compared with the disintegration of large empires with all the subsequent repercussions. The disintegration of a large empire leads to a cascade of new states forming both in the place of the empire and even beyond its borders. Historical detonation contributes to politogenesis the same way as the cosmic detonation contributes to star formation.

Structuring, self-organization and nesting-doll structure The whole history of star-galaxy phase of cosmic evolution is the story of formation of various structures with different size and grouping of these structures into larger ones. At the same time, as we already mentioned, we deal here with the ability of objects to self-organize at all phases of universal and individual evolution. It is very important that structuring occurs not only among stars and galaxies but also among molecular clouds. The latter can be regarded as a parallel branch of evolution. Parallelism plays a great role in evolution dramatically increasing the opportunities of transition to something new and creating a field of contacts between various directions of evolution (see about it below).

They generally have a rather complex 'Russian nesting doll' structure, whereby smaller and denser condensations are placed within larger and sparser ones (see Surkova 2005: 48). The Russian-doll structure is also typical for higher levels of evolution. Thus, smaller groups of social and gregarious animals constitute larger groups and tend to reproduce their structure. The same refers to social evolution, in particular to the non-centralized entities: for example, the tribal formations, whose constituent parts (lineages, clans, and sub-tribes) often reproduce the structure (and structural principles) of the tribe. That is why tribes can easily split and merge when necessary. The same is true of herds of gregarious animals.

Synthesis of gradualism and catastrophism. With respect to cosmic evolution one may observe a combination of two principles that provoke endless discussions in geology and biology. The subject of those discussions is what principle prevails in evolution. Are we dealing mostly with slow gradual changes, eventually leading to major changes (gradualism)? Or, does the development mostly proceed through sharp revolutionary breakthroughs which in biology are often connected with catastrophes? Within star-galaxy evolution the combination of both principles is more than just evident. Here, as at no other evolutionary level, both modes of evolution are organically combined in individual fates of the stars. The main sequence phase of stellar evolution (when the fusing of hydrogen occurs) demonstrates the gradual character and the importance of slow and prolonged processes. However, catastrophes of various scales can take place within the lifetime of any star. For some stars, such radical changes may manifest in major – but still local – changes (such as shedding the outer layers), whereas for other stars these might be tremendous catastrophes when stars die, figuratively speaking, 'brightly' and 'heroically', illuminating the Universe, leaving a billion-year-long footprint of light. The latter, that is the extraordinary phenomena and events, both among the stars and among humans are less numerous than the former, that is the common ones.

2. Some Evolutionary Ideas in Connection with the Star-Galaxy Phase of Evolution of the Universe

In the evolutionary process of formation of stars, galaxies, nebulae, and cosmic clouds one can distinguish a number of important evolutionary principles and laws that are not evident. Their detection is important for understanding the unity of principles of development of the Universe. Those principles and observations are grouped below into several blocks.

2.1. Evolution proceeds with constant creation and destruction of objects

Nature, when creating, destroying, and renewing various objects, 'tests' many versions, some of which turn out to be more effective and have more chances to succeed in terms of evolution. For such a situation of selection within constant destruction and creation process, it appears possible to apply a rather appropriate notion of creative destruction introduced by Josef Schumpeter (1994).

- **'Evolution is stronger than individual objects'.** Cosmic processes are accompanied by constant emergence, development, change, and death of various objects (stars, galaxies, and so on). Thus, here one can point as relevant the principle that was expressed by Pierre Teilhard de Chardin (1987) with respect to life in the following way: 'life is stronger than organisms', that is, life goes on exactly because organisms are mortal. The same is relevant to stellar evolution. We may say here that the cosmos is stronger than stars and galaxies; and in general, evolution is stronger than individual objects.
- **Rotation and keeping balance** take place due to constant destruction (or transition to new phases in the lifecycle) of some objects and the emergence of others. This keeps balance and creates conditions for development, because development is a result of change of generations and species.
- **In every end there is a beginning. Star-evolutionary 'relay race'.** The material of dead objects becomes building blocks for the formation of new objects. This represents the circulation of matter and energy in nature; on the other hand, this represents a sort of 'relay race'.[10]

10 For more details on the 'rule of evolutionary relay race'

The latter allows using the results of long-lasting processes (in particular, the accumulation of heavy elements).[11] Thus, we deal here with the above mentioned 'creative destruction' – the creation of new objects due to the destruction of the old ones, which ensures continuity and provides new forms with space for advancement (*e.g.*, the change of generations of biological organisms always results in certain transformations). The change of rulers may not necessarily lead to radical social changes; however, each new ruler is somehow different from his predecessor, as a result the accumulation of historical experience occurs.

- **New generations of organisms and taxa are a mode of qualitative development.** One may also detect generations of taxa, which already have significant evolutionary and systemic differences. Thus, generations of stars differ in terms of their size, chemical composition, and other characteristics. Only through the change of several generations of objects this class of objects acquires some features that, nevertheless, are considered to be typical for the whole class of objects (thus, biological species are defined when, in nature, it is not possible for matings between individuals from each species to produce fertile offspring. However, many species reproduce asexually).

2.2. Individuality as a way to increase evolutionary diversity

- **Individual fates within evolution.** It appears possible to maintain that with the formation of stars one observes the emergence of individual objects in nature, 'individuals' that, on the one hand, are rather similar, but have rather different individual fates much depending on circumstances of their birth and various contingencies. For example, stars with small masses (in which nuclear fusion occurs at a slow rate) can use all of their fuel (*i.e.*, remain in the main sequence) for many billions of years. On the other hand, blue giants (in which the rate of fuel consumption is rapid and which lose most part of their mass due to their instability) burn out hundreds of times faster.

The stars can end their lives in a rather different way. Some of them, having lost one or a few outer layers, would cool, slowly transforming into cold bodies; some others may contract a few dozen times, or may end their lives with huge explosions blowing their matter into open space. Finally, a star may become a black hole that does not allow any matter to come out of its immensely compressed depths.

- **Ontogenesis and phylogenesis.** The evolution proceeds at various levels: through the development of its certain branch, a certain class, species and so on (and sometimes even at the level of an individual organism). In addition, applying biological terminology, at every level of evolution we find a combination of processes of *ontogenesis* and *phylogenesis*. Of course, within star-galaxy evolution the phylogenesis is represented much weaker than in the evolution of life. Nevertheless, it still appears possible to speak about the history of transformation of certain types of galaxies and stars, and, hence, up to a certain extent the cosmic phylogenesis does occur (see as above with respect to change of a few generations of stars and galaxies that differ from each other as regards their size, structure, and composition).
- **Phases of individual development (ontogenesis) generate trillions of different destinies.** Every type of objects has their own regular phases of life which depend on both internal characteristics of an object and its environment (proximity of other objects, *etc.*). As we have already pointed above, stars have very different duration of the phase which is called the main sequence (from several tens of millions years to 10–15 billion of years and even more) depending on their mass, composition and

see Grinin, Markov, and Korotayev 2008; Grinin 2017.

11 For example, the Solar System emerged from the remnants of a supernova explosion. It is believed that due to this fact there are so many heavy and super-heavy elements on the Earth and other planets.

other characteristics. As was mentioned above, the fate of stars at the last stage of their life also depends on their mass and other circumstances. Depending on this they can turn into the White Dwarf, become a neutron star or a Black Hole.

- **Required and excessive variation as conditions of a search for new evolutionary trajectories.** Within the processes described above one can observe the formation of the taxonomic diversity of space objects; we may even speak about occupying the evolutionary 'niches'. There emerge different types of stars with different masses, luminosity (accordingly, different spectrum/color of the light), temperature, system (single stars, planet systems and systems of stars from two to seven), period of rotation, magnetic field, *etc.* The same refers to the galaxies among which one can distinguish a number of types (elliptical, spiral, and lenticular) and subtypes. Such diversity is extremely important. Only the achievement of a necessary level of taxonomic and other diversity allows a search for ways to new evolutionary levels. This is sometimes denoted as the rule of necessary and excessive diversity (see Grinin, Markov, and Korotayev 2008: 68–72; for more details see also Panov 2008).
- **Norm, averages, and deviation from a norm.** Only when we find a sufficient diversity, it appears possible to speak about norm, average level, exceptions, and outliers. Scientists have long known that the breakthroughs to new forms usually happen at the periphery, and in those systems that diverge from the previous mainstream.
- **Continuity,** which actually means the emergence of a continuum of forms, sizes, life spans, and lifecycles, is rather characteristic for space objects. Thus, the stars can be presented as a continuum from heavier to lighter ones (whereas the latter become hardly distinguishable from planets, their temperature prevent thermonuclear reactions, *etc.* The types of planetary systems uniformly cover a wide range of parameters. There is also a sequence of phases in the transformation of cosmic clouds into stars: condensation of clouds – formation of protostars – formation of young stars, and up to the death of stars. The continuum of forms and sizes of objects may be observed at geological, biological, and social phases of the evolution.

2.3. Object, environment, competition, development systems, and self-preservation

- **The relations between structure and environment.** Multilevel systems (galaxy – galaxy cluster – galaxy supercluster) act as systems of a higher order for stars, and, simultaneously, they create an environment that produces an enormous influence on those stars. A star directly interacts with its immediate environment (*e.g.*, with neighboring stars because of the strong gravity which affects the movement of both stars), whereas with the distant environment the interaction proceeds at higher levels. Within star-galaxy evolution the role of environment is generally less important than at other evolutionary levels, because single stars are separated by great distances and that is why collide rather infrequently. On the other hand, one should not underestimate the role of the environment. For example, the role of the immediate environment is very important in systems of double, triple, or multiple stars. On the whole, single stars are separated by great distances and that is why they collide rather infrequently except for the center of the galaxies where star density is much higher. Here the frequency of collisions is one per a million years (Shklovskii 1978: Ch. 1). For a small galaxy the influence of neighboring larger galaxy may turn out to be fatal, if it leads to its absorption. *External factors* play the major role in *changes* (*e.g.*, a large cosmic body can pass by a giant molecular clouds, there can occur a star explosion, and so on) and may trigger the process of formation of stars and galaxies (by launching the gas contraction process). Collisions of cosmic bodies may create new cosmic bodies – for example, there is a hypothesis that the Moon emerged as a result of the collision of some large objects with the Earth.

With the development of a certain form of evolution, its own laws and environment gain a growing influence on the development of its objects and subjects. For example, both abiotic nature and the biotic environment influence biological organisms. However, within a complex ecological environment, it is the intraspecies and interspecies competition that may have larger influence than any other natural factors, whereas within a complex social environment it is just the social surrounding that affects individuals and social systems more than the natural forces do. Thus, with the formation of star-galaxy structure of the Universe there emerged macro-objects which start to interact with environments which are larger by many orders of magnitude.

- **The formation of evolutionary driving forces of development.** The study of cosmic evolution shows that evolutionary driving forces emerge just at this phase of evolution (although they turn to have small-scale impact on 'progress'). Of course, evolutionary changes are determined by the influence of physical or chemical forces, but we observe them sometimes in the form of preadaptations. For example, the emergence of organic chemical compounds in the clouds of molecular gas exemplifies such a preadaptation. In principle such kinds of complex compounds do not play a significant role in cosmic evolution, but they are 'in support' of development. It is of interest that it is just a peculiar structure of such clouds that protect molecules from cosmic radiation thus, making their existence possible. In other words, preadaptations require specific conditions. In biology preadaptations often emerge in peculiar environment. Thus, it is supposed that at the origin of the amphibians the crossopterygian fins (which already in many ways resembled the amphibian limbs) were transformed into primitive limbs (serving to support body on a solid ground) in the situation of shrinking shallow water.
- **The urge toward self-preservation and origins of the struggle for resources.** Stars, galaxies, and planets (as well as other cosmic bodies) have their definite, quite structured, and preserved form. The 'struggle' for the preservation of those forms, the capacity to live and shine, the use of different layers to minimize energy losses lead to a slow but evident evolutionary development. This way the atomic composition of the Universe changes, whereas the diversity of variations of the existence of matter increases. The bilateral transition of matter into atomic (in hot bodies) or molecular state (in cold structures, in particular in the clouds of gas and in stellar outer layers) and vice versa when forming stars from giant clouds is the brightest manifestation of this type of evolution, a background preparing the formation of its biochemical and biological forms.

On the one hand, the emergence of structures that strive for their preservation creates a wide range of interaction between the system and its environment; on the other hand, this creates a basis for the 'evolutionary search' and evolutionary advancement. This evolutionary paradox – *the struggle for the self-preservation is the most important source for development* – can be observed here in its full-fledged form. However, star-galaxy evolution demonstrates the emergence of this driving force which will become very important in biological evolution; and it appears to be the most important driving force in social evolution. This is 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. We have already mentioned above 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 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.

- **External factors as triggers of transformations** play a great role, for example, when a large celestial object passes close to giant molecular clouds or a star explodes, *etc.* this can launch the process of stars and galaxies formation (*i.e.* trigger gas concentration). The collisions between celestial bodies can form new objects. Thus, it is supposed that the Moon emerged as a result of a collision of a large object with the Earth. The shockwave from a nearby supernova may have been such a trigger for the birth of the Sun about two million years before its collapse started (see Adushkin *et al*. 2008, 276; Bizzarro *et al*. 2007; Grinin 2017, 2018).

Thus, we can formulate *rule of necessary triggering phenomena or events to launch evolutionary process*. A push or trigger is often needed to launch the phase transition or transformation of an object. On the one hand, the latter will not work without internal readiness of a system, but on the other – even a high level of internal readiness cannot start up the transformation process itself, like gunpowder cannot explode without fire. Without a trigger, the system can remain in the state of potential readiness for transformations for a long time. In this case, analogues of evolutionary typical / recognized systems emerge.

1.4. **Multilinearity**

Multilinearity is one of the most important characteristics of evolution. Unfortunately, it does not get sufficient attention, and there is a tendency to reduce evolution to a single line – the one that has produced the highest complexity level, which is often interpreted as the main line of evolution. *However, at every stage of evolutionary development one can find an interaction of a few lines that can have rather different futures*. In other words, in addition to the main evolutionary line one can always identify a number of lateral ones. Firstly, they contribute to the increasing diversity; secondly, they allow expanding the range of search opportunities to move to new levels of development; thirdly, the lateral lines may partly enter the main evolutionary stream, enriching it. We quite often deal with two or more coexisting and comparable lines of development whose convergence may lead to a quantitative breakthrough and synergetic effect. Various lines of development may transform into each other. Elsewhere we have written a lot on the issue of social evolution in this context (see, *e.g.*, Grinin and Korotayev 2009; Grinin and Korotayev 2011; Bondarenko, Grinin, and Korotayev 2011; Grinin 2011).

- **Classical forms and their analogues.** The main and lateral lines of evolution may be considered in two dimensions: 1) horizontal (as regards complexity and functions), 2) vertical (concerning the version that would be realized later at higher evolutionary phases). It appears also possible to speak about classical versions and their analogues. Thus, various forms of aggregation and specialization of unicellulars can be regarded as analogues of multicellulars (see Eskov 2006), whereas various complex stateless polities can be regarded as state analogues (see Grinin and Korotayev 2006; Grinin and Korotayev 2009; Grinin 2011 for more detail). Classical forms and their analogues can transform into each other; however, these are just the analogues that tend to transform into classical forms, rather than the other way round (the latter may be regarded as a forced adaptation to sharply changing conditions, and sometimes even as a direct degeneration).

- **Stars and molecular clouds: two parallel forms of existence of cosmic matter.** In this respect we may consider stars and galaxies as the main line of evolution and the giant clouds as its lateral lines; the former may be denoted as 'classical forms', and the latter may be designated as 'analogues'. On the one hand, those forms actually transform into each other. Galaxies and stars emerge from giant molecular clouds, whereas stars through explosions and shedding their envelopes may transform into gas-dust cloud. On the other hand, giant molecular clouds are able to concentrate; the energy exchange occurs within them, and thus, in terms of gravity and structural complexity they are quite comparable to stars and galaxies[12]. They also exceed stars in the level of organization of elementary particles since molecules are concentrated in clouds, while elementary particles and nuclei – in stars.[13] Besides, stars when they lose the matter and shed their envelopes and due to an explosion transit into gas-dust state, *i.e.* into interstellar gas which gathers into molecular clouds.

Conclusion: The Formationof Various Evolutionary Lines at the Microworld Level

Astrophysical and astrochemical evolution. Almost from the very beginning of the development of the Universe (when the temperature reached thousands of Kelvin) chemical evolution emerges as accompanying physical and astrophysical evolution. Of course, chemical evolution also occurs within stars with the emergence of heavier elements. However, that was rather the formation of the basis for chemical evolution, because chemical processes involve the reactions which lead to the emergence of new substances. Such processes proceed, first of all, within gas-dust clouds where molecules emerge. Hydrogen molecules are absolutely prevalent quantitatively; however, molecules of water and some other substances also emerged. Chemical evolution goes on also on planets (where it combines with geological, or rather planetary evolution) as well as on small celestial bodies (asteroids and meteorites). At the same time, on the planets where due to volcanism, pressure and other geological processes the temperatures could be high enough, the chemical activity significantly differed from that in cold clouds.

Chemical evolution within cosmic evolution. Following Friedrich Engels (and his 'Dialectics of Nature' [Engels 1940]), the representatives of dialectic materialism stated that the chemical form of organization of matter is evolutionarily higher than the physical one. However, in contrast with biological and social forms which from their very origin displayed substantially higher levels of organization of the matter, the chemical form (that emerged almost immediately after the physical form) did not represent a higher form of evolution for a rather long period of time. This is not the case of geological (or rather planetological) evolution which emerged on the planets long time ago and advanced evolution (including the chemical one) through the formation of various minerals and of more comfortable temperature conditions for the development, as well as formation of atmospheres and even of hydrosphere in some places (like on Mars). However, the further evolutionary progress became possible only as a preparation for the formation of appropriate conditions for life on Earth.

That is not to say that chemical evolution is not important in the framework of general stellar and galactic evolution; however, before the emergence of the Earth-like planet, the physical and chemical forms of organization of matter should be regarded as equally important; note also that they constantly transform into each other (see also Dobrotin 1983: 89)[14]. The

12 At various levels of generalization, the clouds of the same size are considered the analogues of stars, while of the larger ones – of galaxies.

13 The molecules can also be found in periphery layers of some stars, in the areas with low temperatures.

14 In any case, it is important to note that the thermonuclear

development of astrochemical evolution is not limited by the formation of simple nonorganic molecules. The processes of formation of molecules proceed further towards the formation of organic substances. More than hundred types of organic molecules have been detected in space (including 9–13 atomic molecules) even including ethanol and amino acid Glycine (see Surdin 2001; Surdin and Lamzin 1992; Shklovskii 1978). Naturally, this facilitated the emergence of life in a rather significant way.

The preadaptation is also manifested in the chemical reactions of a peculiar type which proceed in gas-dust clouds 'not in the usual way, but through a quantum-mechanical subbarrier transition, which does not require much kinetic energy from the participants of the reaction' (Surdin, Lamzin 1992). In other words, multilinearity is also expressed in the fact that classical chemical reactions (which could already take place on some planets) have their analogues. As a result, the multilinearity of evolution is further realized in the set of achievements of its various lines (chemical and geological ones), as it happened on Earth, which gave it an opportunity to move to a new evolutionary level.

The Formation of 'Preadaptations' as Points of Future Evolutionary Growth

Within the star-galaxy era the chemical form of development may be regarded as a 'preadaptation' for new levels of evolution. Let us note that in biology the term 'preadaptation' denotes those adaptations that may turn out to be useful in a different environment and to give significant advantages to those species that have them[15] – and generally – to give an impulse to the formation of new taxa.

Within the Big History framework, the principle of 'preadaptation' means that at the level where a preadaptation emerges, it generally plays insignificant role; however, at a new evolutionary level such 'innovations' generally give evolutionary impulses.[16] Respectively, chemical compounds (as is common for preadaptations) do not mean much for cosmic evolution, they were rather 'in reserve' to reveal all their significance at the level of planetary evolution.

I would like to finish this article with a note on one more peculiarity of preadaptations. Appropriate conditions are necessary for their formation. Within biological evolution, the preadaptations often emerge in peculiar environments. Thus, it is supposed that the transformation of fins of the fleshy-finned fish (from which Amphibia descended) into primitive legs occurred within the environment of shallow waters that often dried out. In a similar way, within star-galaxy evolution the emergence of complex chemical compounds can take place only within certain structures of cosmic clouds that made their existence possible as they protected the molecules from cosmic radiation.

Conclusion

So it is important to summarize our approach which, in our opinion, is fruitful in the field of Big History, as in any other researches about evolutionary analogues between cosmology, society and biological world.

We can see different mechanisms, such as: catastrophes, self-preservation, interaction with environment, struggle for resources, formation of individual objects, formation of the main and lateral lines, diversity, selection, etc., which demonstrate the commonality of evolutionary rules and patterns in different phase of Big History and different levels of evolution. Unfortunately we can't pay enough attention to each mechanism and rule, because for a detailed explanation it would be necessary to write a special article.

It would be worth to mention that some authors regard natural selection as the main and sometimes the only one evolutionary mechanism, which works not only in biological stage of Big History, but in

reactions make the chemical evolution of the Galaxy proceed in a single direction, namely, from simple to complex elements (Surdin and Lamzin 1992). This also refers to evolution in general.

15 This omnivorous ability of hominids allowed their transition to hunting at a very early phase of the anthropogenesis.

16 On preadaptations in megaevolution see also Grinin, Korotayev, and Markov 2011: 159–160.

cosmological stage too. Without any doubt selection is important and along with other evolutionary mechanisms can provide insights of the formation of the large-scale structure of the Universe. However, as the reader can understand, we regard the selection mechanism only as one of the most important for cosmology, but by no means the main one, and, moreover, not the only one.

Nevertheless, one cannot but give credit to many interesting cosmological hypotheses. For example, David Baker explores the selection mechanism among an enormous number of universes in the 'multiverse'. However, his algorithm with respect to the selection of universes could hardly be called properly Darwinian. He rather speaks about the evolutionary selection in general – that is not the selection of the fittest, but rather the selection of those capable to evolve – which is much wider than the Darwinian selection. The idea that such selection is not Darwinian is confirmed if one employs Christian's (2014) and Smolin's (2008) works[17].

In conclusion, we want to repeat the objectives of the article. First of all, we used a historical narrative showing the origin and development of general evolutionary models and then explaining them to give an idea of the formation of the large-scale structure of the Universe.

Secondly, the goal was to find evolutionary similarities at different levels and to use them for the analysis of commonality of evolutionary rules and patterns in different systems.

We did not try just to apply already formulated evolutionary principles of different complex biological or social systems to the cosmological issues. This method can be wrong, since many of such principles will be unsuitable in cosmology.

Thirdly, but, rather briefly, some questions were discussed about analogues of functioning and developing between various objects and systems.

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17 Smolin often refers to the anthropic principle as a very important evolutionary idea, which we did not touch in the article.

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A Era Astro-Galáctica em Termos da Macro-História e da Evolução Universal

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Resumo

O presente artigo tenta combinar o potencial da Macro-História com o potencial dos Estudos Evolucionários. Não apenas analisando a história do Cosmos. Mas também estudando semelhanças entre leis, princípios e mecanismos evolutivos em vários níveis e fases da Macro-História. Essa abordagem abre algumas novas perspectivas para nossa compreensão da evolução e da Macro-História, suas forças motrizes, vetores e tendências; e cria um campo consolidado para pesquisa interdisciplinar. De especial importância é o ponto em que muitos princípios, padrões, regularidades e regras da evolução, que tendemos a achar relevantes apenas para os níveis biológicos e sociais da evolução, também podem ser aplicados à fase cósmica da evolução. Isso não é tão surpreendente, já que a formação, o ciclo de vida e a renovação de estrelas, galáxias e outros corpos celestes é o processo evolutivo mais longo que ocorreu no Universo.

Palavras-chave

Era Astro-Galáctica, fase cósmica da Macro-História, leis da evolução, princípios evolutivos universais, Universo, pré-adaptações, Estudos Evolutivos, seleção evolutiva, modelos de evolução aditivos e substitutivos, estruturas em larga escala do Universo, nuvens de poeira de gás, concentração não uniforme de matéria, circulação de matéria no Universo, matéria escura e clara.

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Introdução

"O esforço para entender o Universo é uma das poucas coisas que eleva a vida humana um pouco acima do nível da farsa e lhe dá um pouco da graça da tragédia." Essas palavras ditas pelo ganhador do Nobel Steven Weinberg (1977: 155) merecem, sem dúvida, atenção, embora dramatizem as origens do interesse acerca dos problemas do Universo. De fato, não precisamos de nenhuma justificativa para explicar o desejo de entender as origens de todos os seres vivos. Essa aspiração de perceber o mundo em sua totalidade está na psique humana, é uma característica integrante da mente, pelo menos de um certo tipo de pessoas que sempre querem alcançar as causas últimas (embora seja um caminho sem fim). Além disso, nas últimas décadas, a investigação do mundo em sua totalidade (mas não em seus aspectos separados) foi intensificada em particular dentro do campo da Macro-História.

A Macro-História oferece oportunidades únicas para considerar o desenvolvimento do Universo como um processo unificado, para detectar vetores de mudanças de certas características importantes do Universo (como complexidade e energia) em várias fases desse desenvolvimento. Alguns autores analisam importantes mecanismos e padrões evolutivos gerais, que podem ser vistos em todas as fases da Macro-História (por exemplo, Christian 2004, 2014; Spier 2010; Baker 2013). Entretanto, deve-se notar que os estudos da Macro-História tendem a prestar pouca atenção a um aspecto tão importante quanto a unidade de princípios, leis e mecanismos de evolução em todos os seus níveis. Acredito que combinar o potencial da Macro-História com abordagens evolutivas pode abrir horizontes mais amplos nesse aspecto (ver Grinin et al. 2011). De fato, traços comuns de desenvolvimento, funcionamento e interação podem ser encontrados em processos e fenômenos macro-históricos aparentemente bastante diferentes. A esse respeito, a universalidade da evolução é expressa naquelas semelhanças reais que são detectadas em muitas manifestações em todos os seus níveis.

Este artigo continua as tentativas do autor de combinar o potencial da Macro-História com o potencial dos Estudos Evolutivos, a fim de alcançar os seguintes objetivos: 1) aplicar o princípio da narrativa histórica à descrição da era das galáxias-estrelas da fase cósmica da Macro-História; 2) analisar tanto a história cósmica quanto as semelhanças e diferenças entre leis, princípios e mecanismos evolutivos em vários níveis e fases da Macro-História; 3) mostrar como a evolução cósmica se encaixa nos algoritmos evolutivos universais e se correlaciona com as leis e padrões evolutivos comuns. Pouquíssimos pesquisadores abordaram essa tarefa de maneira sistemática. Parece especialmente importante demonstrar que muitos princípios, padrões, regularidades e regras evolutivas, que tendemos a achar relevantes apenas para os níveis mais altos e para as principais linhas de evolução, também podem ser aplicados à evolução cósmica. Além disso, quase tudo o que sabemos sobre evolução pode ser detectado na história cósmica, já que muitas das características evolutivas já se manifestam de maneira bastante clara e distinta. Também devemos ter em mente que a origem das galáxias, estrelas e outros "objetos celestes" é o processo evolutivo mais longo de todos os processos evolutivos do Universo. Essa abordagem abre algumas novas perspectivas para nossa compreensão da evolução e da Macro-História, suas forças motrizes, vetores e tendências; e cria um campo consolidado para pesquisa interdisciplinar.

Ao estudar a questão, ficou claro que o número de semelhanças e características comuns do progresso evolutivo em seus vários estágios e níveis é extremamente grande, que elas podem ser reveladas nos processos e fenômenos aparentemente os mais diferentes. Quase tudo o que sabemos sobre evolução já pode ser encontrado em sua fase cósmica (ver também Grinin 2013, 2014a, 2014b, 2015a, 2015b, 2017, 2018, 2019). Naturalmente, muitos fenômenos são revelados de forma rudimentar ou não sistemática, mas várias características, pelo contrário, são mais claramente expressas justamente na fase cósmica. E, ao mesmo tempo, quando características e aspectos da evolução biológica ou social revelam inesperadamente suas raízes ou formas iniciais em fases anteriores, fica claro que a universalidade da evolução é uma realidade encontrada em muitas manifestações.

Nosso mundo é imensamente diversificado e ilimitado em suas manifestações. No entanto, fundamentalmente, é um mundo único - é por isso que é tão importante estudar esses fundamentos.

I. A FORMAÇÃO DA ESTRUTURA EM GRANDE ESCALA DO UNIVERSO

Pré-condições. Após o Big Bang, nosso Universo "viveu" por um longo período de tempo sem estrelas, galáxias, aglomerados e superaglomerados de galáxias (Khvan 2008: 302)[1]. A formação da estrutura moderna do Universo durou bilhões de anos. No entanto, as primeiras estrelas e galáxias surgiram entre 200 e 400 milhões de anos depois do Big Bang (por exemplo, ver European Commission, 2011). Vamos discutir isso em detalhes a seguir. E qual foi a matéria de onde elas emergiram?

Aproximadamente 270.000 anos após o Big Bang, ocorreu uma grande transição de fase, resultando no surgimento de matéria na forma de átomos de hidrogênio e hélio. Mais tarde, eles começaram a se con-

1 Ver Gorbunov e Rubakov 2012; Guth 1997 Guth A. 2002; Guth 2004; Wood 2018; Grinin 2018 sobre o Big Bang e os problemas teóricos associados a ele.

solidar em novas estruturas (veja abaixo). A principal massa dessa matéria concentrava-se em nuvens de poeira de gás que poderiam ter tamanhos tremendos (dezenas de parsecs ou até mais).[2]

Hoje em dia, podemos falar sobre esses fragmentos cósmicos, como gás interestelar e poeira cósmica. Eles podem ser encontrados em um estado muito rarefeito ou na forma de nuvens. Mas sabe-se que as nuvens que observamos atualmente consistem em gás e poeira, na maioria das vezes em proporções iguais. Portanto, geralmente se fala de nuvens de gás e poeira.

Pela primeira vez, observamos a Natureza no papel de construtora. Antes disso, ela havia formado apenas os elementos básicos. Agora era possível observar o surgimento de estruturas enormes a partir de pequenas "partículas de poeira". Depois disso, foi possível observar esse fenômeno constantemente: estruturas de grande escala são compostas por miríades de partículas e grãos.

As sementes necessárias para a estrutura. A formação de nuvens (e mais tarde estrelas e galáxias) significou uma concentração de matéria em enorme escala, que poderia ter sido causada apenas pela gravidade. No entanto, essa única força é insuficiente para a estruturação, porque "em um universo absolutamente homogêneo é impossível o surgimento de estruturas de grande escala (galáxias e seus aglomerados)" (Dolgov et al. 1998: 12–13). Assim, certas sementes são necessárias - isso é comparável à formação de gotas de chuva que emergem em torno de partículas de poeira ou fuligem; ou com a formação de uma pérola em torno de areia.

Muitas vezes, são necessárias pequenas flutuações para que as forças poderosas comecem a trabalhar. Na verdade, pequenas flutuações (pequenos desvios da homogeneidade) ocorreram no Universo desde o princípio. Então as maiores flutuações aconteceram. Eles poderiam atuar como sementes para a formação de galáxias e a matéria se concentrou em torno deles em uma escala muito maior até que a quantidade começasse a se transformar em uma nova qualidade. No entanto, não está claro que tipo de flutuações causaram a formação de galáxias e qual é o mecanismo de sua formação. As flutuações iniciais em outras esferas evolutivas também permanecem um mistério.

Este é um exemplo perfeito do ponto em que a não uniformidade (em particular no que diz respeito à distribuição de matéria, energia etc.) é uma característica universal. Qualquer grande mudança evolutiva nos sistemas biológicos e sociais é precedida pela concentração de certas formas, recursos e condições em determinados nichos e lugares. Quanto maior o estágio da evolução, mais significativo é esse processo. Assim, no sistema principal, os processos comuns podem prosseguir da maneira usual, enquanto na zona de concentração começam alguns processos peculiares (isso é o que ocorre nas zonas de formação estelar).

Assim, podemos formular uma regra evolutiva sobre flutuações e heterogeneidade importantes. O surgimento da heterogeneidade crítica, que pode ser o núcleo das mudanças, é frequentemente necessário para a mudança evolutiva (mesmo dentro das estruturas de uma transformação típica sem crescimento evolutivo qualitativo). Uma homogeneidade absoluta impossibilita alguns processos evolutivos, ao passo que a menor diferença pode desencadear o reagrupamento de matéria ou elementos na montagem. E, assim, uma nova estrutura e ordem surgem nessa base (consulte Grinin 2017, 2018 para mais detalhes).

A era de formação das estruturas em larga escala no Universo As primeiras galáxias e estrelas

Matéria escura e clara. Atualmente, é geralmente aceito que a matéria escura desempenha um papel importante na formação das primeiras galáxias, pois pareceu capaz de se consolidar em aglomerados muito antes da matéria clara (bárions). Esta última não pôde se contrair até o final da recombinação do hidrogênio (formação de átomos) devido à radiação (270.000 anos após o Big Bang). Somente quando núcleos de hidrogênio e elétrons foram capazes de fundir e formar átomos, ao passo que os fótons se separavam da matéria e voavam para longe, a pressão da radiação caiu drasticamente. Talvez estejamos observando aqui

2 1 parsec ≈ 31 trilhões de quilômetros.

um padrão evolutivo muito interessante de uma transição da desordem para a ordem e de entropia decrescente. Esse caso se correlaciona bastante bem com o princípio universal de evolução de Herbert Spencer (Spencer 1862: 495, 1970: 396)[3] Ele a formulou como uma lei da transição de uma substância durante seu desenvolvimento qualitativo, de homogeneidade indefinida (não diferenciada e não especializada) para heterogeneidade definida (mais especializada). Como resultado, a matéria clara cairia em buracos potenciais preparados pela matéria escura. Embora a matéria escura fosse inicialmente mais capaz de estruturar do que a matéria clara, o progresso em direção à estruturação acabou sendo muito curto e levando a quase um impasse.[4] Enquanto isso, o potencial evolutivo da matéria clara foi baseado nas "realizações da matéria escura". Esse modelo de desenvolvimento é bastante típico da evolução. Por exemplo, muito antes da transição para a agricultura, alguns coletores de cereais inventaram muitas coisas (foices, celeiros e pedras de moer) que mais tarde se tornaram bastante úteis para os agricultores, enquanto caçadores-coletores especializados se tornaram um beco sem saída evolutivo.

A era de formação das estruturas em larga escala no Universo As primeiras galáxias e estrelas

Existem opiniões bastante diversas sobre o tempo, as características do processo e a sequência de formação de estrelas, galáxias, aglomerados e superaglomerados de galáxias. Existe uma hipótese de que os protoaglomerados de galáxias foram os primeiros a se originar. Segundo essa hipótese, o mesmo processo que gerou a galáxia poderia operar em uma escala maior, e a primeira geração de nuvens de gás seriam os protoaglomerados que se fragmentaram para formar as galáxias (Peebles, 1980). Fenômenos semelhantes podem ser encontrados em níveis mais altos de evolução, quando algo geral é formado (o que mais tarde se tornará um táxon maior na hierarquia) e depois se diferencia em táxons de ordem mais baixa. É assim que espécies e classes são formadas em biologia. O mesmo se refere a uma sociedade: a princípio emergem formações bastante grandes, como famílias de línguas e depois as línguas, super grupos étnicos e depois grupos étnicos, e às vezes grandes impérios ou estados; e depois, dentro de sua estrutura, o estado se especializa um ou dois níveis. Em outras palavras, emerge uma grande estrutura não diferenciada, capaz de produzir um grande número de estruturas peculiares.

No entanto, uma hipótese mais comumente aceita sugere que as protogalaxias (na forma de nuvens gigantes de gás condensado) foram as primeiras a emergir dentro da estrutura do Universo e depois se tornaram o berço de estrelas e outros elementos estruturais (ver, por exemplo, Gorbunov e Rubakov 2011).

No entanto, nos últimos anos, novas evidências surgiram para apoiar a ideia de que foram as estrelas que apareceram primeiro. Essa descoberta, de alguma forma, modificou as teorias anteriores. Atualmente, é amplamente aceito que as estrelas foram as primeiras a surgir, mas essas eram estrelas gigantes, muito mais massivas do que a maioria das estrelas formadas posteriormente (May et al. 2008). Devido à ausência de carbono, oxigênio e outros elementos que absorvem a energia das nuvens condensadas, o processo prosseguiu mais lentamente naquela época; assim, apenas nuvens gigantes poderiam condensar-se produzindo estrelas massivas centenas de vezes maiores que o Sol (Ibid.). Atualmente, também podemos encontrar gigantes que têm entre 100 e 200 massas solares, mas

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3 É interessante que ele dê um exemplo conectado ao sistema solar. "Se o Sistema Solar existiu em um estado de homogeneidade indefinida e incoerente, e progrediu para seu estado atual de heterogeneidade definida e coerente; então o Movimento, o Calor e a Luz agora exibidos por seus membros são interpretáveis como correlatos de forças pré-existentes; e entre eles e seus antecedentes, podemos discernir relações que não são apenas qualitativas, mas também rudemente quantitativas.

4 Entretanto, como em qualquer beco sem saída evolutivo, isso não significa uma estagnação absoluta. Atualmente, nos halos da galáxia, a matéria escura está estruturada em certas estruturas menores (ver, por exemplo, Diemand et al. 2008).

elas são consideradas instáveis (ver Surdin, Lamzin, 1992). Tais estrelas gigantes viveram apenas alguns milhões de anos (quanto maior a estrela, menor a sua vida). Além disso, as primeiras estrelas continham uma pequena quantidade de elementos pesados. Assim, mais de uma geração de estrelas poderia passar, até que a quantidade de elementos pesados aumentasse gradualmente. O surgimento de "elementos pesados" dos "restos mortais das estrelas" se assemelha à formação de sedimentos marinhos ou solo fértil na superfície da Terra a partir do acúmulo de esqueletos ou da conversão de restos de plantas mortas. A circulação da matéria no Universo é sempre observada em todos os lugares e em todos os níveis.

Nos últimos anos, testemunhamos a descoberta de algumas galáxias que são consideradas as mais antigas do Universo. Enquanto isso, as datas de formação das primeiras galáxias são deslocadas cada vez mais perto do Big Bang. O surgimento das primeiras galáxias é datado de menos de 400 milhões de anos após o Big Bang; e há até alegações de que algumas galáxias mais antigas foram descobertas. Alega-se que eles surgiram apenas 200 milhões de anos após o Big Bang (ver European Commission 2011). A evidência nas primeiras estrelas refere-se a cerca de 150–200 milhões de anos após o Big Bang - portanto, estrelas e galáxias parecem ter surgido quase simultaneamente. Desde então, a substância no Universo coexiste em três formas principais, dependendo de sua densidade: em um estado denso nos corpos celestes, em uma forma rarefeita em nuvens de tamanhos diferentes e em um estado altamente rarefeito (dezenas de vezes se comparado a nuvens) no gás interestelar.

Assim, as galáxias foram formadas ativamente durante os primeiros 300-400 milhões de anos após o Big Bang. No entanto, embora algumas estruturas já tivessem surgido na época, ainda não eram dominantes no Universo, e ainda eram muito amorfas e instáveis (Hawking 1998). A formação de uma estrutura de grande escala mais ou menos estável levou algum tempo, provavelmente alguns bilhões de anos. Como mencionamos acima, a formação de vários elementos pesados sem os quais a criação de estrelas resilientes era impossível também levou tempo. A formação do Universo próximo à estrutura moderna dificilmente poderia ocorrer rapidamente.

II. A ERA DA ESTRUTURA ASTRO-GALÁCTICA DO UNIVERSO

Toda a história da fase estrela-galáxia da evolução cósmica é basicamente a história da formação de várias estruturas de tamanhos diferentes, bem como sua fusão em estruturas maiores (mas também é uma história de sua desintegração). A formação de galáxias e seus aglomerados, bem como de estrelas e outros corpos celestes, foi o processo evolutivo mais longo que já ocorreu no Universo. Atualmente, observamos que esse processo ainda está ocorrendo ao lado de mudanças e desaparecimentos de galáxias e estrelas. Durante os primeiros oito bilhões de anos, a formação de uma enorme diversidade de corpos estelares e novos elementos pesados ocorreu no Universo até cerca de 5 a 4,5 bilhões de anos atrás, lá surgiram as condições para a formação de sistemas estelares (como o Sistema Solar). Em um dos planetas do Sistema Solar, iniciaram-se novos processos geológicos, químicos e bioquímicos (para mais detalhes, ver Christian 2004; Lin 2008; Batygin et al. 2016; Grinin 2017, 2018).

1. A estrutura do universo

1.1. Princípios evolutivos da estrutura do Universo. A formação de galáxias e seus aglomerados foi provavelmente um processo que durou bilhões de anos. Alguns princípios que descrevem a estrutura básica do Universo podem ser aplicados a diferentes níveis de evolução (abaixo, consideraremos apenas dois deles).

1) A combinação de qualidades antagônicas. Por exemplo, na estrutura do Universo, pode-se encontrar a combinação de uniformidade e não uniformidade. A uniformidade já se manifesta na fase de inflação, quando o Universo começou a inflar uniformemente em todas as dimensões. A uniformidade foi preservada até o presente, mas apenas na maior escala (de uma ordem de magnitude de 100 megaparsecs). Para referência, o tamanho dos maiores aglomerados de galá-

xias (como nosso Grupo Local com o centro na constelação de Virgem) é de no máximo 40 megaparsecs (Gorbunov e Rubakov 2011). A não uniformidade do Universo se manifesta em escalas menores que 100 megaparsecs; e quanto menor é a escala, mais saliente é a irregularidade. A combinação de qualidades antagônicas é um fenômeno que é bastante característico para muitos outros níveis evolutivos. Assim, as noções antagônicas como "superfície homogênea" e "superfície irregular" são bastante aplicáveis à superfície da Terra: aos olhos dos pássaros, a superfície parece homogênea.

2) Densidade e dispersão podem ser rastreadas em toda parte, começando pela estrutura atômica, onde a massa está concentrada em um núcleo minúsculo, enquanto a maioria do átomo é um espaço vazio. Existe uma enorme não uniformidade entre a escala do Universo e o espaço que a massa principal da matéria clara ocupa dentro dela (pelo menos, bariônica). Ela concentra-se, antes de tudo, em estrelas, que na verdade ocupam apenas uma parte de 10^{-25} do volume total do Universo (sem levar em conta os núcleos das galáxias [Pavlov 2011: 43]). Havia tais proporções no universo antigo? Provavelmente não. Portanto, a concentração da matéria está aumentando. Não apenas a matéria dura é distribuída de maneira muito desigual pelo Universo; o mesmo vale para o gás. Grande parte desse gás está concentrada em nuvens moleculares gigantes, que são de muitos milhares de massas solares (Lipunov 2008: 37).

Ao mesmo tempo, a diferença de densidade é fractal, o que é especialmente evidente nas zonas de alta densidade. Os fatores que contribuem para essa desigualdade nem sempre são claros; por exemplo, não está claro com o que estão relacionados a distribuição desigual de massas durante a formação de galáxias (Weinberg, 1977) e muitos outros processos de distribuição, como a concentração e dissipação.

Mas os princípios de distribuição desigual da massa de matéria em diferentes níveis evolutivos são bastante semelhantes. Por exemplo, atualmente a massa principal da população da Terra está concentrada em um território bastante pequeno em comparação com o território total em que a vida na Terra é possível.

1.2. A estrutura atual do Universo

Os principais elementos estruturais do Universo são galáxias, seus aglomerados e superaglomerados. Os superaglomerados formam basicamente nossa Metagaláxia[5]. Todos os elementos estruturais são bastante estáveis em termos de gravitação, embora possam se dividir, fundir e colidir.

As galáxias são entidades estruturais integrais com uma estrutura bastante complexa que inclui, além de regiões e braços, um núcleo (centro), semi-periferia (chamada "disco") e periferia (chamada "auréola") (Baade 2002: 255) A auréola consiste tanto de estrelas separadas quanto de vários aglomerados estelares. O raio da auréola (algumas centenas de milhares de anos-luz) é muito maior que o raio do disco da galáxia. [6]

Segundo Hubble, as galáxias são classificadas como espirais, elípticas e irregulares com vários subtipos (Ibid.: 18–32); no entanto, mais um tipo de galáxia foi identificado - as galáxias lenticulares.

> Uma galáxia contém cerca de 100 a 200 bilhões de estrelas. Existem galáxias pequenas (anãs) com alguns milhões de estrelas, também existem galáxias gigantes que consistem de até um trilhão de estrelas. Nossa galáxia, com sua massa de cerca de 10^{11} massas solares, é uma das maiores. Ele contém de 200 a 300 (ou ainda

5 Se, de acordo com alguns pesquisadores, a Metagaláxia não é a única no Universo, por algum tempo será considerada a maior unidade estrutural do Universo (Pavlov 2011: 52). Se o Universo não é um Universum, mas um assim chamado Multiverso, os Universos ou seus grupos serão a unidade máxima da estrutura (ver Vilenkin 2006; 2010).

6 Pode haver uma auréola invisível que consista de matéria escura atrás da auréola visível. Ela pode ser encontrada em muitas (se não em todas as) galáxias, nas quais o diâmetro da auréola escura pode exceder o diâmetro da auréola visível em uma ordem de magnitude (ver Ryabov et al. 2008: 1131).

mais) bilhões de estrelas. No entanto, a massa da nossa vizinha - a Nebulosa da Grande Andrômeda (M31, encontrada em nosso aglomerado de galáxias (o Grupo Local)) - é cerca de três vezes maior. Provavelmente, o M87, mais famoso, situado na parte central do aglomerado de galáxias na constelação de Virgem, possui a maior massa. Aparentemente, a massa desta galáxia excede em centenas de vezes a massa da nossa galáxia. No outro polo, existem galáxias anãs cujas massas são de aproximadamente 10^7 massas solares, ou seja, dezenas de vezes mais que a massa de aglomerados globulares (Shklovskii 1978: Parte 1, Capítulo 6).

As estrelas estão distribuídas de maneira bastante desigual pelas galáxias, elas são partes de vários grupos e aglomerados; alguns deles consistem em apenas algumas estrelas, mas outros aglomerados podem conter alguns milhões. Por exemplo, dentro de nossa galáxia, mais de 1.500 aglomerados de estrelas foram identificados (Surdin 2001). Existem muitos aglomerados globulares - aglomerados esféricos fortemente ligados pela gravidade e consistindo de centenas de milhares de estrelas, quase sempre, bastante antigas. Essas são estrelas antigas (existem entre 50 e 200 em nossa galáxia). Elas são cerca de 22% das estrelas entre as galáxias mais próximas. Nessas galáxias, um corpo achatado principal e brilhante, "uma lente", é cercado por uma auréola fraca. Às vezes, a lente é cercada pelo anel (ver: Novikov 1979: cap. 1, § 8). Mais da metade dos membros do Grupo Local são galáxias elípticas mais antigas com luminosidade intermediária ou baixa (Novikov 1979: 31). As galáxias são sistemas complexos e (em grande parte) auto-reguláveis, nos quais algumas estrelas se desintegram, enquanto novas estrelas se formam a partir de gás e poeira cósmicos. A circulação (que resulta em processos de renovação da matéria e sua mistura) ocorre em todos os níveis do Universo - tanto espacialmente quanto em diferentes níveis de complexidade evolutiva.

Um aglomerado de galáxias médio consiste de 500 a 1000 galáxias. Os aglomerados de galáxias têm uma estrutura bastante regular que gerallmente inclui um núcleo maciço no centro. Os superaglomerados de galáxias são entidades que consistem de 2 a 20 aglomerados de galáxias e grupos de galáxias, além de galáxias isoladas. São conhecidos mais de 20 superaglomerados, incluindo o nosso Grupo Local (Gorbunov, Rubakov 2012: 4).

1.3. Gerações de galáxias e estrelas

Existem opiniões bastante diversas sobre o número de gerações ao longo da evolução do Universo. Além disso, não há consenso sobre quais galáxias devem ser consideradas antigas e quais galáxias devem ser consideradas jovens. O ponto é que dentro de uma única galáxia é possível encontrar estrelas e seus agregados que diferem consideravelmente em tipo, idade e outros parâmetros. Por exemplo, a idade da nossa Via Láctea é superior a 12 bilhões de anos, mas essa é apenas a sua auréola, enquanto muitas estrelas em suas ramificações têm apenas dois a cinco bilhões de anos ou ainda menos. No entanto, parece possível destacar algumas idéias básicas amplamente aceitas.

1) Na evolução do Universo, houve três (ou pelo menos duas) gerações de galáxias e estrelas. Em geral, as galáxias antigas são menores e de brilho mais fraco. Suas estrelas contêm dezenas de vezes menos quantidades de elementos pesados que o Sol. Os astrônomos dificilmente podem observar qualquer processo de formação de estrelas nessas galáxias. Existe também a hipótese de que mais massa escura se concentre nas galáxias antigas em comparação com as mais jovens. Da mesma forma, estrelas mais velhas e mais jovens diferem entre si em tamanho, luminosidade e composição química.

2) É difícil falar de uma clara periodização de gerações de galáxias, devido ao processo contínuo de formação de galáxias e estrelas. As galáxias precisam renovar constantemente sua composição para manter sua identidade. Como Iosif Shklovskii sustenta, a esse respeito as galáxias são muito semelhantes às florestas primárias com sua mistura de idades das árvores (enquanto a idade das árvores é muito menor que a idade da própria floresta [Shklovskii 1978]). A motilidade e variabilidade da paisagem celeste se assemelha muito

à motilidade das paisagens geológicas.

3) A formação de galáxias pode ocorrer de diferentes maneiras, por exemplo, através da absorção de galáxias menores pelas maiores, em particular como resultado de uma colisão. Se uma pequena galáxia entra em colisão com uma enorme, é absorvida pela última e perde sua identidade. Toda vez que passam perto de uma galáxia massiva, as estrelas de uma galáxia pequena se separam dela (May et al. 2008). Nesse caso, agrupamentos jovens e velhos de estrelas são misturados (veja abaixo). Outra maneira é a fusão de galáxias. Às vezes, as galáxias das gerações mais jovens podem se formar através do acúmulo de algumas galáxias pequenas, fracas e compactas em uma única galáxia. Nesse caso, eles se tornaram "blocos de construção" para galáxias. Finalmente, pode acontecer que duas galáxias grandes colidam. Tal colisão pode levar bilhões de anos e ser acompanhada por formação estelar ativa e surgimento de estrelas muito grandes e brilhantes. As últimas características significam que estas são estrelas de vida curta, ou seja, haverá muitas explosões de nova e supernova. Finalmente, as galáxias podem divergir novamente, mas neste caso elas se mostram muito diferentes do que costumavam ser antes da colisão, enquanto uma galáxia a mais pode emergir da matéria separada das duas galáxias (ver May et al. 2008: 142).

Existem inúmeras analogias para esses modelos de formação de galáxias na evolução biológica, geológica e, principalmente, social. Como estrelas e galáxias são compostas de matéria mais ou menos homogênea (que pode ser dividida ou unida com bastante facilidade), elas de alguma forma se assemelham paradoxalmente a sociedades que consistem em pessoas que podem ser incluídas em outras sociedades por meio de integração ou captura. Por outro lado, as capturas também são vistas entre animais sociais (por exemplo, entre formigas, veja Genet 2007).

4) Galáxias são coleções de diferentes tipos de estrelas. Entretanto, existem certas peculiaridades em relação à posição de estrelas velhas e jovens nas galáxias que provavelmente estão relacionadas à auto-regulação nos sistemas galácticos ou às peculiaridades da formação de estrelas que ocorrem em grandes grupos ou devido a outros fatores (sobre a auto-regulação no mundo cósmico, ver Grinin A. 2016). Assim, dentro de nossa galáxia, as estrelas mais jovens (como o Sol, que tem alguns bilhões de anos) são geralmente maiores, mais quentes e mais brilhantes. Elas estão localizadas em próximas ao plano do disco e, principalmente, dentro dos braços da galáxia; enquanto na periferia da galáxia (em sua auréola), encontramos estrelas mais velhas com mais de 12 bilhões de anos (o que sugere a idade geral da galáxia). No entanto, estrelas mais velhas e mais jovens também podem estar localizadas bem próximas umas das outras. Assim, pode-se encontrar muitas estrelas antigas perto do centro da galáxia (protuberância), mas também existem estrelas jovens que emergiram da matéria produzida pela desintegração das estrelas mais antigas. A maior densidade estelar é encontrada no centro da galáxia, onde atinge algumas estrelas por parsec cúbico.

Como já mencionamos, as estrelas muito antigas, com pouco brilho, pouco calor e pouca massa contêm quantidades muito menores de elementos pesados que o Sol. Não é de surpreender que essas estrelas mais velhas e as estrelas jovens, quentes e brilhantes da superfície do disco, braços e auréola tenham sido rotuladas diferentemente como "População I" e "População II", respectivamente.[7] É geralmente aceito que a maioria dos aglomerados globulares é muito antiga (12 bilhões de anos ou mais). Mas os aglomerados galácticos dispersos ou abertos são dezenas ou até cem vezes mais jovens que os aglomerados globulares (ou seja, têm apenas centenas de milhões de anos). Mas existem associações estelares mais jovens (ver, por exemplo, Surdin e Lamzin 1992; Surdin 2001).

Por um lado, a preservação de gerações de estre-

7 Observe que, quando apareceu uma evidência da existência das estrelas da primeira geração que surgiram na idade do Universo de 150 milhões de anos desde o momento do Big Bang (veja acima), elas foram nomeadas "População III "para seguir a designação convencional.

las e galáxias demonstra um caráter aditivo da evolução dos sistemas abióticos, enquanto que podemos ver elementos do modelo substitutivo da evolução na fase biológica e seu sistema completo na fase social da Macro-História. No entanto, a captura de estrelas e galáxias com sua subsequente integração e processos prolongados de colisão de galáxias demonstra que em sistemas naturais abióticos ainda podemos encontrar alguns outros modelos de evolução - conectados com “guerras” e “submissão de estrangeiros”.

O tipo de desenvolvimento através do surgimento de diferentes gerações de indivíduos e espécies (preservando certas características genéticas, por um lado, e acumulando mudanças importantes em sua estrutura e características, por outro) é bastante difundido em todas as fases e níveis da evolução universal . Dentro de qualquer classe ou ordem biológica (por exemplo, perissodáctilos), podemos ver como as características importantes variam e mudam gradualmente de uma espécie para outra, enquanto que, devido a essas características, algumas espécies extinguem outras e ocupam nichos melhores (veja, por exemplo, Grinin, Markov, e Korotayev 2008). Vários tipos de estados e civilizações também ilustram de maneira bastante vívida o progresso: por exemplo, estados mais organizados e desenvolvidos emergem através da absorção das realizações de gerações menos desenvolvidas de estados, que podemos ilustrar usando exemplos da história da Roma Antiga, Bizâncio, alguns estados europeus medievais e assim por diante. A coexistência de gerações diferentes às vezes leva à situação em que entidades mais jovens e mais avançadas transformam as mais antigas ou formam uma simbiose com elas (embora em alguns lugares possam ser encontradas “restrições” para tipos e gerações mais velhos).

1.4. Alteração da composição química do Universo

O hidrogênio sempre foi o elemento mais abundante na composição química do Universo; no entanto, sua participação diminuiu constantemente. Isso ocorreu (e ocorre) porque o hidrogênio é o principal combustível das reações de fusão nuclear que sustentam a vida e a luminosidade das estrelas. Apesar das enormes quantidades de energia liberadas durante essas reações, a taxa de liberação de energia é muito baixa. Por exemplo, a intensidade da radiação solar é de 2 erg/g·s, o que é quase igual a uma pilha de folhas em chamas. As estrelas brilham intensamente porque são massivas e enormes (Surkova 2005: 9).

O aumento da temperatura dentro do núcleo de algumas estrelas foi necessário para a formação de novos elementos ausentes na era da recombinação. No entanto, todas as reações de fusão que ocorrem para produzir elementos maiores que o ferro não liberam mais energia. Reações de outro tipo são necessárias para a formação de elementos mais pesados que o ferro - a energia consumida por essas reações é maior do que a energia liberada. É por isso que existem quantidades relativamente pequenas de elementos pesados no Universo. No entanto, essas reações peculiares ocorrem - por exemplo, em estrelas de nêutrons e durante explosões de supernovas. Nas supernovas, durante suas explosões, em apenas 100 segundos são formados elementos pesados do final da tabela periódica de Mendeleev, incluindo urânio e tório (Surkova 2005: 9).

Quando as supernovas explodem, elementos pesados são expelidos através do Universo com ventos estelares e através da queda da matéria dispersa na superfície dos corpos celestes (a chamada acreção). Como as estrelas se mostram os principais centros da síntese de elementos químicos, a distribuição de elementos pesados no Universo é muito pouco homogênea.

O surgimento de elementos pesados e sua concentração em certos corpos e composições são processos extremamente importantes, que levam a um enorme aumento no número de combinações de matéria e, consequentemente, têm um potencial evolutivo; em particular, eles levam ao início dos processos químicos, bioquímicos e biológicos em grande escala. Em certos aspectos, essa acumulação lenta e desigual de novos elementos estruturais (elementos pesados) se assemelha ao processo de acumulação de mutações valiosas na evolução biológica ou acumulação de inovações valiosas na evolução social (todas elas trazem a expansão da evolução potencial e aumentam as taxas de mudanças evolutivas).

As semelhanças e diferenças de composições estelares (a presença de elementos pesados) se parecem, em alguma medida, com as semelhanças e diferenças no genoma. Todos os organismos vivos têm essa mesma estrutura semelhante e todas as grandes diferenças são causadas por pequenas divergências (em vários pontos porcentuais) nos genes.

2. A evolução das galáxias e das estrelas

2.1. Processos de formação de galáxias e estrelas

Até bem recentemente, os processos de formação de estrelas eram inteiramente inacessíveis para um observador externo; no entanto, atualmente, devido ao progresso tecnológico, podemos observar alguns aspectos desses processos em muitas partes da nossa galáxia. Essas observações confirmam a teoria da formação estelar a partir de aglomerados frios que são aquecidos por gravitade e pressão.

Resumidamente, esse processo pode ser descrito da seguinte maneira. Nas nuvens gigantes de hidrogênio e hélio, emergem algumas heterogeneidades, que iniciam (sob certas condições) os processos de gravitação que começam a coletar essa massa em formas esféricas. Às vezes, ocorre uma formação direta de uma massa gigante de nuvens de gás, da qual emerge uma galáxia ou um aglomerado de estrelas. Nesse caso, a fragmentação das nuvens pode ocorrer e, assim, mais e mais esferas de nuvens de gás (podem existir centenas de milhões, ou mesmo centenas de bilhões) emergem, as quais podem gradualmente se transformar em protoestrelas. Esse processo continua até o ponto em que a densidade do gás se torna tão alta que cada novo fragmento já possui a massa de uma estrela (Surkova 2005: 49). Então a gravidade começa a impedir mais fragmentação. Esse processo é descrito como "fragmentação em cascata". É notável que se assemelhe a certos processos na evolução social - por exemplo, a fragmentação de grandes estados antigos em partes separadas que descentralizam até o ponto em que uma divisão adicional se torna implausível (por exemplo, em certos períodos, houve dezenas e centenas de estados independentes nos territórios da Alemanha ou da França).

À medida que enormes nuvens de gás / poeira parecem instáveis, elas se desintegram em grandes feixes, assim a formação de estrelas prossegue em grupos. Esse fenômeno é de interesse não apenas no que diz respeito à evolução estelar. A formação de grupos é bastante típica da evolução em geral (desse modo, populações e às vezes novas espécies emergem; chefias, cidades-estado e às vezes partidos políticos emergem em grupos, e assim por diante).

O processo adicional da formação estelar está conectado ao ponto em que a compressão inicial aqueceu o gás a uma temperatura bastante alta o que, por um lado, impede a compressão adicional do gás e, por outro lado, contribui para o início da reação de fusão nuclear (Hawking 1998).

II.2. Diversidade de estrelas e galáxias

A diversidade é uma condição absolutamente necessária do desenvolvimento evolutivo. E essa condição é totalmente efetivada dentro da evolução cósmica. Como foi mencionado acima, as galáxias diferem em seus tipos, idade, tamanho e estrutura. Elas também diferem em muitas outras características, incluindo composição química e o sistema imediato ao qual pertencem, por exemplo, se são estrelas binárias ou isoladas, se as estrelas têm ou não um sistema planetário, etc. Essas diferenças podem variar bastante.

O impacto variável da gravitação e o comportamento peculiar resultante das massas de nuvens de gás podem se tornar o motivo da formação de diferentes tipos de galáxias. Isso significa que as galáxias nascem como espirais ou elípticas e o tipo de galáxia é preservado no curso de sua evolução. Em particular, uma estrutura galáctica é em grande parte determinada pelas condições iniciais de sua formação (por exemplo, pelo caráter de rotação do grupo de gases original a partir do qual uma galáxia é formada).

As estrelas diferem em massa, temperatura, composição química, luminosidade, idade e outras características. Essas diferenças podem variar bastante. Por exemplo, no que diz respeito às massas, as estrelas variam em massa de cerca de 0,1 a 100 ou mais massas solares. Existem algumas considerações de que as fusões termonucleares não podem acontecer em uma estrela com massa inferior a 8% da massa solar, razão pela qual esses objetos não são descritos como estrelas. É bastante natural que o número de entidades menores seja ordens de magnitude maiores que o número de entidades maiores[8]; na verdade, o mesmo fenômeno pode ser observado, por exemplo, em Zoologia ou Geografia Política, onde o número de pequenos animais ou países é muito maior que o dos grandes.

II.3. O ciclo de vida de uma estrela: Estágios de nascimento, envelhecimento e morte estelares

Protoestrelas. Como mencionado acima, as estrelas emergem através da condensação e compressão de nuvens de gás sob a influência de forças gravitacionais. Esta é uma fase protoestelar. Em comparação com a vida subseqüente de uma estrela, o período de sua lenta contração parece bastante curto; no entanto, na verdade, esse não é um processo rápido, pois às vezes demora até 50 milhões de anos (Surkova 2005: 50). Durante esse período, há um tremendo aumento da temperatura no centro da protoestrela, a temperatura pode crescer de 8 a 10 milhões Kelvin e, como resultado, reações termonucleares se tornam possíveis. A protoestrela se torna uma estrela jovem. No entanto, um observador externo só poderá vê-la em algumas centenas de milhares (ou mesmo alguns milhões) de anos, quando o casulo de gás e poeira ao redor da protoestrela se dissipar.

Na verdade, lidamos com uma espécie de milagre - um corpo incandescente gigante e brilhante, capaz de viver bilhões de anos, emerge de um absolutamente amorfo, uma névoa de gás sem estrutura, opaca e fria. Em outras palavras, lidamos aqui com um exemplo vívido de auto-organização que ocorre sob a influência das leis da gravitação e da termodinâmica. Em particular, uma intensa contração leva ao aquecimento, o que aumenta a pressão interna, o que, eventualmente, interrompe o processo de compressão (para mais detalhes sobre os processos de surgimento de estrelas jovens, incluindo a observação direta deles e o nascimento do Sol, consulte Marakushev. et al. 2013; Marov et al. 2013; Grinin 2017, 2018).

Pode-se notar também que o surgimento de estrelas e galáxias deve ter um certo gatilho que cria turbulência e heterogeneidade. Esses gatilhos e catalisadores são os componentes inerentes dos mecanismos evolutivos que podem ser encontrados em muitos processos: em processos químicos e geológicos, na evolução biológica com relação à formação rápida de espécies ou na evolução social com relação à formação de estados (ver Grinin 2011 para mais detalhes). A onda de choque da supernova, a colisão de uma nuvem molecular com braços espirais de uma galáxia e outros eventos podem se tornar um gatilho da formação estelar (Surkova 2005: 50).

Outra (a mais longa) macrofase é a estrela de sequência principal. Durante esta fase da vida estelar, as reações de fusão nuclear que transformam hidrogênio em hélio no núcleo mantêm a estrela brilhando. É por isso que a duração da fase de sequência principal depende principalmente da massa estelar. Quanto mais maciça for a estrela, menor será sua vida útil na sequência principal (como em uma massa maior, os processos de "queima de combustível" são mais intensos). Uma estrela preserva seu tamanho e forma devido à luta mútua de duas forças: a gravidade que tenta comprimir a estrela e a pressão do gás produzida como resultado de reações nucleares e do forte aquecimento. Existe um equilíbrio dinâmico entre temperatura e pressão do gás. Com a temperatura crescente, o gás se expande e trabalha contra as forças da gravitação, o que resulta no resfriamento da estrela; desta forma, o equilíbrio térmico é mantido. Durante a vida de estrelas e galáxias, bem como em todos os outros níveis de

8 Assim, para cada dez milhões de anãs vermelhas, encontramos apenas 1.000 gigantes e uma supergigante (Surkova 2005: 26).

evolução, encontramos numerosos casos e formas diferentes de interação entre dois processos opostos, que possibilitam a vida de "indivíduos". Os processos de assimilação e dissimilação dão suporte às atividades vitais dentro de organismos biológicos; os processos de reprodução animal e seu extermínio por predadores sustentam o equilíbrio da população; a interação entre processos de produção e consumo é a base da reprodução dos sistemas sociais, e assim por diante.

Gigantes vermelhas. A nova fase da evolução estelar está ligada ao esgotamento dos estoques de hidrogênio. A pressão do gás (que mantinha o equilíbrio estelar quando o combustível necessário estava disponível) diminui e o núcleo estelar é comprimido. Isso leva a um novo aumento de temperatura. Uma estrela começa a queimar elementos mais pesados e, portanto, a composição estelar muda significativamente. Simultaneamente à compressão do núcleo, as camadas externas da estrela se expandem (elas podem até se desprender para formar uma nebulosa gasosa). Em geral, a estrela infla e expande atingindo um tamanho algumas centenas de vezes maior, se transforma em uma gigante vermelha e, em seguida, com mais expansão - em uma supergigante vermelha (grandes estrelas com mais de dez massas solares se transformam diretamente em supergigantes). Essa fase dura cerca de um décimo da "vida ativa" de uma estrela, enquanto os processos de fusão nuclear prosseguem em suas profundezas.

Morte em estrela: três casos. A próxima fase é a transformação de uma gigante vermelha ou supergigante. Na verdade, a nova forma depende da massa estelar e de várias outras características, como a rotação e velocidade estelares, o grau de sua magnetização e assim por diante. Os três resultados a seguir são considerados os mais típicos. Eles dependem da massa estelar (mas as estimativas do valor limite variam significativamente e, portanto, abaixo mencionarei os principais valores alternativos após a barra)[9]. Estrelas com massas menores que 1,2-1,4 / 3 massas solares se transformam de gigantes vermelhas em chamadas "anãs brancas", quando a estrela lança seu envelope externo para formar uma nebulosa planetária com um núcleo extremamente contraído (até o tamanho da Terra). A compressão adicional não ocorre devido à chamada pressão gerada pelo gás de elétrons que não depende da temperatura. Como resultado, a anã branca é bastante estável. No entanto, devido à falta de hidrogênio e hélio, as fusões termonucleares não podem mais prosseguir dentro dessa estrela. Uma anã branca está muito quente quando é formada; contudo, depois a estrela esfria e se transforma em uma "anã negra", isto é, torna-se um corpo cósmico morto e frio.

Para estrelas com massa inicial superior a 1,2-1,4, mas inferior a 2,4-3 (em outros cálculos de 3 a 7-10), o envelhecimento lento e gradual resulta em um "infarto", que é um colapso. Após o esgotamento do hidrogênio e a diminuição da pressão interna do gás (que costumava equilibrar a gravidade), sob a influência da gravidade o núcleo fica extremamente comprimido (dezenas de milhares de vezes - até o raio de dez quilômetros), em menos de um segundo. Quase simultaneamente, as camadas externas da estrela são sopradas com uma velocidade enorme como resultado de uma onda de choque. Essa supernova brilha mais que milhões de estrelas comuns, mas por um período muito curto de tempo. Essa explosão expele o material estelar para o meio interestelar e, portanto, ocorre a formação de quantidades consideráveis de elementos pesados (mais pesados que o ferro) que depois se concentram em vários corpos celestes. O núcleo restante se contrai para se tornar uma estrela de nêutrons (que deveria conter um fluido super denso de nêutrons). Em seu tamanho, essa estrela é 5 bilhões de vezes menor que o Sol, mas é centenas de milhares de vezes mais brilhante porque a temperatura em sua a superfície é

9 De acordo com uma das classificações (que pode ser mais correta do que a reproduzida abaixo), parece possível subdividir todas as estrelas apenas em duas classes: a) estrelas massivas (com uma massa superior a 10 massas solares) que produzem estrelas de nêutrons e buracos negros e b) não massivas, que produzem anãs brancas (Lipunov 2008: 99).

1000-1500 vezes maior que a do Sol (Lipunov 2008: 133).

Se a massa estelar exceder o limite de 3/7 a 10 massas solares, depois que o hidrogênio for queimado, ele começará a entrar em colapso e a explodir (embora às vezes possa entrar em colapso sem uma explosão), mas a força de compressão será ilimitada, à medida que a gravidade se tornar enorme por causa da enorme massa e ausência de forças internas que podem impedir o colapso. A ação da força gravitacional que age sem contrapesos leva à situação em que o diâmetro estelar se torna infinitesimalmente pequeno. De acordo com cálculos teóricos, a estrela é transformada em um buraco negro cujos campos de gravidade são fortes demais para a luz escapar.

III. PRINCÍPIOS EVOLUCIONÁRIOS UNIVERSAIS NA ERA ASTRO-GALÁCTICA

1. Vida, Morte e Catástrofes no Aspecto Evolutivo

O caráter irreversível da evolução é sua característica mais importante. A evolução pode ser observada como um movimento constante para estruturas e formas de organização mais complexas, em direção à mudança da composição química do Universo, etc. Quanto aos objetos individuais, o caráter irreversível da evolução é óbvio e inquestionável. Uma estrela que passou por uma certa fase da vida não pode entrar novamente nessa fase. **A vida estelar em termos de manutenção e quebra do equilíbrio dinâmico.** Na fase inicial, uma nuvem de gás "queima" a si mesma sob a compressão, como palha ou trapos acesos espontaneamente. A próxima fase da auto-organização está conectada com a formação de estrutura estelar complexa na fase principal da sequência, durante a qual ocorre queima do hidrogênio. Depois de queimar a maior parte do hidrogênio, uma estrela entra em uma nova fase, se expande e se transforma em uma gigante vermelha. Ao mesmo tempo, os processos de auto-organização recomeçam e a estrutura estelar muda radicalmente (o núcleo altamente compactado coexiste com os envoltórios expandidos). Depois que o combustível é queimado em uma gigante vermelha, a próxima fase é a compressão sob a influência da força gravitacional e a formação de uma estrutura totalmente nova: um núcleo pequeno, mas muito massivo, com densidade extremamente alta da matéria dentro dele.

Consideremos a vida estelar em termos de manutenção e quebra do equilíbrio dinâmico. Primeiro de tudo, há um equilíbrio térmico, quando a taxa de energia produzida no núcleo (através de fusões termonucleares) equilibra a perda de energia através da emissão de radiação no espaço. Esse equilíbrio é quebrado quando o combustível de hidrogênio se esgota. As reservas são aparentemente compensadas quando uma estrela começa a usar outro tipo de energia. Isso pode ocorrer através da contração da estrela, que começa a fundir hélio em carbono, produzindo muitas vezes mais energia para cada átomo; posteriormente, os elementos mais pesados podem ser usados como combustível, e cada elemento mais pesado produzirá mais e mais energia por átomo. Enquanto isso, o núcleo da estrela começa a aumentar de temperatura. Há equilíbrio em termos de pressão de forças diferentes e preservação de uma certa forma e tamanho da estrela. Na fase da sequência principal , o equilíbrio é mantido à medida que a gravidade puxa toda a matéria estelar para dentro, em direção ao núcleo, enquanto a pressão do gás empurra o calor e a luz para longe do centro. Essa pressão existe até que as reservas de combustível nuclear se esgotem (Efremov 2003: 97). Em relação às gigantes vermelhas, pode-se falar em equilíbrio de outro tipo em duas dimensões. No núcleo, a temperatura aumenta devido à contração e começam as reações termonucleares de níveis mais altos (descritos acima); como resultado dessas reações, a temperatura pode crescer até 100 milhões de Kelvin. É por isso que uma gravidade mais forte é equilibrada por uma pressão de gás mais forte (devido à temperatura). Enquanto isso, dentro do envólucro, o equilíbrio é alcançado através da expansão múltipla das camadas externas. Nas estrelas de nêutrons e nas anãs brancas, as fases subsequentes da vida estelar, existe o seu equilíbrio peculiar.

O problema da morte do indivíduo. A morte como uma oportunidade para a vida continuar. Vida e morte estelares dificilmente podem deixar alguém indiferente. Na verdade, dentro da estrutura da Macro-História, é a primeira vez que nos deparamos com o problema de um ciclo de vida de objetos individuais de uma forma tão explícita. Por um lado, o destino, a vida útil e o tipo de morte da estrela dependem dos parâmetros iniciais, como se fossem "programados geneticamente" (e, portanto, podem ser previstos); por outro lado, eles podem ser alterados por algumas contingências. Assim, o destino da estrela não é "fatal", de fato. Os sistemas estelares binários aumentam muito a variabilidade dos destinos estelares individuais; como diz Lipunov (2008: 252), tratamos aqui de uma espécie de "evolução quadrática". Além disso, é realmente possível falar sobre diferenças no comportamento estelar "individual" ou "dentro de um grupo", porque a interação de duas, três ou mais estrelas pode levar a diferenças muito significativas e resultados incomuns que não podem surgir dentro a trajetória de desenvolvimento de estrelas individuais. De fato, padrões semelhantes são observados em outros níveis de evolução, quando o comportamento de pares ou grupos de indivíduos produz resultados radicalmente diferentes daqueles observados em relação ao comportamento de um indivíduo que não interage com os outros.

Finalmente, o significado da morte do indivíduo para a evolução pode ser diferente. Até um certo grau, pode-se observar uma correlação direta entre a "força" da morte, o poder da explosão estelar e a formação de condições para uma nova busca evolutiva. Explosões estelares afetam a dinâmica de seu ambiente; consequentemente, elas podem ajudar a criar condições incomuns que contribuem para o surgimento de certos desvios de desenvolvimento. Dentro de dezenas de milhares de anos, a zona de explosão se expande para uma vasta área de meio interestelar (cobrindo as distâncias de dezenas de parsecs); nesta área, pode-se ver a formação de novas condições físicas (em particular temperatura, densidade de raios cósmicos e força dos campos magnéticos). Tal distúrbio enriquece a respectiva zona com raios cósmicos e traz mudanças na composição química (Shklovskii 1978). As explosões também contribuem para a formação de estrelas. Assim, uma estrela não morre em vão. Pode-se traçar aqui uma analogia interessante com extinções na evolução biológica que contribuem para novas direções da especiação. A destruição estelar também pode ser comparada à desintegração de grandes impérios, com todas as repercussões subsequentes. A desintegração de um grande império leva a uma cascata de novos estados se formando tanto no lugar do império quanto além de suas fronteiras. Detonações históricas contribuem para a politogênese da mesma maneira que as detonações cósmicas contribuem para a formação de estrelas.

Estrutura, auto-organização e estrutura de bonecas aninhadas Toda a história da fase astro-galáctica da evolução cósmica é a história da formação de várias estruturas com diferentes tamanhos e agrupamentos dessas estruturas em estruturas maiores. Ao mesmo tempo, como já mencionamos, lidamos aqui com a capacidade dos objetos de se auto-organizarem em todas as fases da evolução universal e individual. É muito importante que a estruturação ocorra não apenas entre estrelas e galáxias, mas também entre nuvens moleculares. Este último pode ser considerado como um ramo paralelo da evolução. O paralelismo desempenha um grande papel na evolução, aumentando drasticamente as oportunidades de transição para algo novo e criando um campo de contatos entre várias direções da evolução (veja abaixo).

Eles geralmente têm uma estrutura bastante complexa de "boneca russa", na qual condensações menores e mais densas são colocadas dentro de outras maiores e mais escassas (ver Surkova 2005: 48). A estrutura de bonecas russas também é típica para níveis mais altos de evolução. Assim, grupos menores de animais sociais e gregários constituem grupos maiores e tendem a reproduzir sua estrutura. O mesmo se refere à evolução social, em particular às entidades não centralizadas: por exemplo, as formações tribais, cujas partes constituintes (linhagens, clãs e sub-tribos) frequentemente reproduzem a estrutura (e os princípios estruturais) da tribo. É por isso que as tribos podem facilmente se dividir e se fundir quando necessário. O mesmo se aplica aos rebanhos de animais gregários.

Síntese de gradualismo e catastrofismo. No que diz respeito à evolução cósmica, pode-se observar uma combinação de dois princípios que provocam discussões intermináveis em geologia e biologia. O assunto dessas discussões é o princípio que prevalece na evolução. Estamos lidando principalmente com mudanças graduais lentas, que eventualmente levam a grandes mudanças (gradualismo)? Ou, o desenvolvimento ocorre principalmente por meio de grandes e revolucionárias descobertas que na biologia geralmente estão conectadas a catástrofes? Dentro da evolução da estrela-galáxia a combinação de ambos os princípios é mais do que apenas evidente. Aqui, como em nenhum outro nível evolutivo, ambos os modos de evolução são organicamente combinados nos destinos individuais das estrelas. A fase de seqüência principal da evolução estelar (quando ocorre a fusão do hidrogênio) demonstra o caráter gradual e a importância de processos lentos e prolongados. No entanto, catástrofes de várias escalas podem ocorrer durante a vida útil de qualquer estrela. Para algumas estrelas, essas mudanças radicais podem se manifestar em grandes - mas ainda locais - mudanças (como soltar as camadas externas), enquanto para outras estrelas essas podem ser tremendas catástrofes quando as estrelas morrem, figurativamente falando, "brilhantemente" e "heroicamente", iluminando o Universo, deixando uma pegada de luz de um bilhão de anos. Os últimos, quais sejam os fenômenos e eventos extraordinários, tanto entre as estrelas quanto entre os humanos, são menos numerosos que os primeiros, que são os comuns.

2. Algumas idéias evolucionárias relacionadas à fase astro-galáctica da evolução do Universo

No processo evolutivo de formação de estrelas, galáxias, nebulosas e nuvens cósmicas, pode-se distinguir uma série de princípios e leis evolutivas importantes que não são evidentes. Sua detecção é importante para entender a unidade dos princípios de desenvolvimento do Universo. Esses princípios e observações estão agrupados abaixo em vários blocos.

2.1. A evolução prossegue com a constante criação e destruição de objetos

A natureza, ao criar, destruir e renovar vários objetos, "testa" muitas versões, algumas das quais se mostram mais eficazes e têm mais chances de sucesso em termos de evolução. Para tal situação de seleção dentro de um processo constante de destruição e criação, parece possível aplicar uma noção bastante apropriada de destruição criativa introduzida por Josef Schumpeter (1994).

- **"A evolução é mais forte que os objetos individuais".** Os processos cósmicos são acompanhados por constante surgimento, desenvolvimento, mudança e morte de vários objetos (estrelas, galáxias, etc.). Assim, aqui pode-se apontar como relevante o princípio expresso por Pierre Teilhard de Chardin (1987) com relação à vida da seguinte maneira: "a vida é mais forte que os organismos", ou seja, a vida prossegue exatamente porque os organismos são mortais. O mesmo é relevante para a evolução estelar. Podemos dizer aqui que o cosmos é mais forte que estrelas e galáxias; e, em geral, a evolução é mais forte que os objetos individuais.

- **A rotação e a manutenção do equilíbrio** ocorrem devido à destruição constante (ou transição para novas fases no ciclo de vida) de alguns objetos e o surgimento de outros. Isso mantém o equilíbrio e cria condições para o desenvolvimento, porque o desenvolvimento é resultado da mudança de gerações e espécies.

- **Em todo fim, há um começo. A "corrida de revezamento" da evolução das estrelas.** O material dos objetos mortos se torna um componente essencial para a formação de novos objetos. Por um lado, isso representa a circulação de matéria e energia na natureza; por outro, isso representa uma espécie de "corrida de revezamento"[10]. Este fenômeno permite usar os resultados de processos duradouros (em particular, o acúmulo de elementos pesados)[11]. Assim, lidamos aqui com a "destruição criativa" acima mencionada - a criação de novos objetos devido à destruição dos antigos, o que garante a continuidade e fornece novas formas com espaço para progresso (por exemplo, a mudança de gerações de organismos biológicos sempre resulta em certas transformações). A mudança de governantes pode não levar necessariamente a mudanças sociais radicais; no entanto, cada novo governante é de alguma forma diferente de seu antecessor, como resultado, o acúmulo de experiência histórica ocorre.

- **Novas gerações de organismos e táxons são um modo de desenvolvimento qualitativo.** Pode-se também detectar gerações de táxons, que já possuem diferenças evolutivas e sistêmicas significativas. Assim, gerações de estrelas diferem em termos de tamanho, composição química e outras características. Somente através da mudança de várias gerações de objetos, uma classe de objetos adquire algumas características que são consideradas típicas para toda a classe de objetos (assim como espécies biológicas são definidas quando, na natureza, não é possível acasalamentos entre indivíduos de espécies diferentes produzirem filhotes férteis, por outro lado, muitas espécies se reproduzem assexuadamente).

2.2. Individualidade como forma de aumentar a diversidade evolutiva

- **Destinos individuais dentro da evolução.** Parece possível sustentar que, com a formação de estrelas, observa-se o surgimento de objetos individuais na natureza, "indivíduos" que, por um lado, são bastante semelhantes, mas têm destinos individuais bastante diferentes, dependendo das circunstâncias de seu nascimento e de vários fatores e contingências. Por exemplo, estrelas com massa pequena (nas quais a fusão nuclear ocorre lentamente) podem usar todo o seu combustível (isto é, permanecer na sequência principal) por muitos bilhões de anos. Por outro lado, gigantes azuis (nas quais a taxa de consumo de combustível é rápida e que perdem grande parte de sua massa devido à sua instabilidade) queimam centenas de vezes mais rápido.

As estrelas podem terminar suas vidas de uma maneira bastante diferente. Algumas delas, tendo perdido uma ou algumas camadas externas, esfriariam, transformando-se lentamente em corpos frios; outras podem contrair algumas dezenas de vezes, ou podem terminar suas vidas com enormes explosões lançando sua matéria para o espaço aberto. Finalmente, uma estrela pode se tornar um buraco negro que não permite que nenhuma matéria saia de suas profundezas imensamente compactadas.

- **Ontogênese e filogênese.** A evolução prossegue em vários níveis: através do desenvolvimento de um determinado ramo, uma certa classe, espécie e assim por diante (e às vezes até no nível de um organismo individual). Além disso, aplicando terminologia biológica, em todos os níveis da evolução, encontramos uma combinação de processos de *ontogênese* e de *filogênese*. Certamente, dentro da evolução astro-galáctica, a filogênese é representada de

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10 Para mais detalhes sobre a "regra da corrida de revezamento evolucionário", ver Grinin, Markov e Korotayev 2008; Grinin 2017.

11 Por exemplo, o Sistema Solar emergiu dos restos de uma explosão de supernova. Acredita-se que, devido a esse fato, haja muitos elementos pesados e superpesados na Terra e em outros planetas.

forma muito mais fraca do que na evolução da vida. No entanto, ainda parece possível falar sobre a história de transformação de certos tipos de galáxias e estrelas e, portanto, até certo ponto a filogênese cósmica ocorre (veja acima com relação à mudança de algumas gerações de estrelas e galáxias que diferem entre si em relação ao tamanho, estrutura e composição).

- **As fases do desenvolvimento individual (ontogênese) geram trilhões de destinos diferentes.** Todo tipo de objetos tem suas próprias fases regulares da vida, que dependem das características internas de um objeto e de seu ambiente (proximidade de outros objetos, etc.). Como já apontamos acima, a fase de sequência principal da vida de uma estrela pode ter durações muito diferentes (podendo durar de várias dezenas de milhões de anos a 10-15 bilhões de anos ou ainda mais), dependendo de sua massa, composição e outras características. Como foi mencionado acima, o destino das estrelas no último estágio de sua vida também depende de sua massa e de outras circunstâncias. Dependendo disso, eles podem se transformar em uma anã branca, tornar-se uma estrela de nêutrons ou um buraco negro.

- **Variação necessária e excessiva como condições de uma busca por novas trajetórias evolutivas.** Dentro dos processos descritos acima, podemos observar a formação da diversidade taxonômica dos objetos espaciais e podemos até mesmo falar sobre a ocupação de "nichos" evolutivos. Nesse contexto emergem diferentes tipos de estrelas com diferentes massas, luminosidades (e, consequentemente, espectros / cores diferentes da luz), temperaturas, sistemas (estrelas únicas, sistemas planetários e sistemas de estrelas de duas a sete), período de rotação, campo magnético, etc. . O mesmo se refere às galáxias entre as quais é possível distinguir vários tipos (elípticos, espirais e lenticulares) e subtipos. Essa diversidade é extremamente importante. Somente a conquista de um nível necessário de diversidade taxonômica e outras permite uma busca de caminhos para novos níveis evolutivos. Às vezes, isso é denotado como a regra da diversidade necessária e excessiva (ver Grinin, Markov e Korotayev 2008: 68–72; para mais detalhes, ver também Panov 2008).

- **Norma, médias e desvio da norma.** Somente quando encontramos diversidade suficiente, parece possível falar sobre norma, nível médio, exceções e discrepâncias. Os cientistas sabem há muito tempo que os avanços para novas formas geralmente acontecem na periferia e naqueles sistemas que divergem do mainstream anterior.

- **A continuidade,** que na verdade significa o surgimento de um continuum de formas, tamanhos, expectativa e ciclos de vida, é bastante característica dos objetos espaciais. Assim, as estrelas podem ser apresentadas como um continuum, das mais pesadas para as mais leves (enquanto as últimas se tornam dificilmente distinguíveis dos planetas, porque sua temperatura evita reações termonucleares), etc. Os tipos de sistemas planetários cobrem uniformemente uma ampla gama de parâmetros. Há também uma sequência de fases na transformação das nuvens cósmicas em estrelas: condensação das nuvens - formação de protoestrelas - formação de estrelas jovens e até a morte das estrelas. O continuum de formas e tamanhos de objetos pode ser observado nas fases geológica, biológica e social da evolução.

2.3. Objeto, meio ambiente, competição, sistemas de desenvolvimento e autopreservação

- **As relações entre estrutura e ambiente.** Os sistemas multiníveis (galáxia - aglomerado de galáxias - superaglomerado de galáxias) agem como sistemas de uma ordem superior para estrelas e, simultaneamente, criam um ambiente que produz uma enorme influência sobre essas estrelas. Uma estrela interage diretamente com seu ambiente imediato (por exemplo, com estrelas vizinhas por causa da forte gravidade que afeta o movimento de ambas as estrelas), enquanto que com o ambiente distante a interação prossegue em níveis mais altos. Na evolução das estrelas-galáxias, o papel do ambiente é geralmente menos importante do que em outros níveis evolutivos, porque estrelas únicas são separadas por grandes distâncias e é por isso que colidem com pouca frequência. Por outro lado, não se deve subestimar o papel do meio ambiente. Por exemplo, o papel do ambiente imediato é muito importante em sistemas de estrelas duplas, triplas ou múltiplas. No geral, as estrelas únicas são separadas por grandes distâncias e é por isso que colidem com pouca frequência, exceto pelo centro das galáxias, onde a densidade das estrelas é muito maior. Aqui a frequência de colisões é de uma por milhão de anos (Shklovskii 1978: cap. 1). Para uma galáxia pequena, a influência de uma galáxia vizinha maior pode ser fatal, se levar à sua absorção. *Fatores externos* desempenham o papel principal nas *alterações* (por exemplo, um grande corpo cósmico pode passar por nuvens moleculares gigantes onde pode ocorrer uma explosão estelar etc.) e podem desencadear o processo de formação de estrelas e galáxias (ao iniciar o processo de contração do gás). Colisões de corpos cósmicos podem criar novos corpos cósmicos - por exemplo, há uma hipótese de que a Lua surgiu como resultado da colisão de alguns objetos grandes com a Terra.

Com o desenvolvimento de uma certa forma de evolução, suas próprias leis e ambiente ganham uma influência crescente no desenvolvimento de seus objetos e sujeitos. Por exemplo, tanto a natureza abiótica quanto o ambiente biótico influenciam os organismos biológicos. Entretanto, dentro de um ambiente ecológico complexo, são as competições intraespécies e interespécies que podem ter maior influência do que quaisquer outros fatores naturais, enquanto que em um ambiente social complexo é apenas o ambiente social que afeta mais os indivíduos e os sistemas sociais do que as forças naturais. Assim, com a formação da estrutura astro-galácticas do Universo, surgiram macro-objetos que começaram a interagir com ambientes que são maiores por muitas ordens de magnitude.

- **A formação de forças motrizes evolutivas do desenvolvimento.** O estudo da evolução cósmica mostra que as forças motrizes evolucionárias emergem exatamente nesta fase da evolução (embora elas passem a ter um impacto em pequena escala no “progresso”). Obviamente, as mudanças evolutivas são determinadas pela influência de forças físicas ou químicas, mas as observamos algumas vezes na forma de pré-adaptações. Por exemplo, o surgimento de compostos químicos orgânicos nas nuvens de gás molecular exemplifica essa pré-adaptação. Em princípio, esses tipos de compostos complexos não desempenham um papel significativo na evolução cósmica, mas são um “apoio” ao desenvolvimento. É interessante que apenas uma estrutura peculiar dessas nuvens proteja as moléculas da radiação cósmica, tornando possível a sua existência. Em outras palavras, as pré-adaptações requerem condições específicas. Na biologia, as pré-adaptações geralmente surgem em um ambiente peculiar. Assim, supõe-se que, na origem dos anfíbios, as barbatanas dos Crossopterygian (que já se assemelhavam de várias formas aos membros anfíbios) fossem transformadas em membros primitivos (servindo para sustentar o corpo em solo sólido) em situação de redução das águas rasas.

- **O impulso da autopreservação e as origens da luta por recursos.** Estrelas, galáxias e planetas (assim como outros corpos cósmicos) têm sua forma definida, bastante estruturada e preservada. A "luta" pela preservação dessas formas, a capacidade de viver e brilhar, o uso de diferentes camadas para minimizar as perdas de energia levam a um desenvolvimento evolutivo lento, mas evidente. Dessa forma, a composição atômica do Universo muda, enquanto a diversidade de variações da existência da matéria aumenta. A transição bilateral da matéria para o estado atômico (nos corpos quentes) ou molecular (nas estruturas frias, em particular nas nuvens de gás e nas camadas externas estelares) e vice-versa ao formar estrelas a partir de nuvens gigantes é a manifestação mais brilhante desse tipo de evolução, um pano de fundo que prepara a formação de suas formas bioquímicas e biológicas.

Por um lado, o surgimento de estruturas que buscam sua preservação cria uma ampla gama de interações entre o sistema e seu ambiente; por outro lado, isso cria uma base para a "busca evolutiva" e o avanço evolutivo. Esse paradoxo evolucionário - *a luta pela autopreservação é a fonte mais importante para o desenvolvimento* - pode ser observado aqui em sua forma completa. No entanto, a evolução astro-galáctica demonstra o surgimento dessa força motriz que se tornará muito importante na evolução biológica; e parece ser a força motriz mais importante na evolução social. Esta é a luta por recursos que, entre estrelas e galáxias, podem prosseguir na forma de enfraquecimento de outro objeto ou sua destruição (por exemplo, através de uma transferência direta de energia e matéria de um corpo para outro), na forma de "incorporação", "captura", ou seja, "anexação" de estrelas e aglomerados de estrelas por grupos maiores. Já mencionamos acima coalescências galácticas. Assim, alguns astrônomos afirmam que, ao longo de alguns bilhões de anos, nossa galáxia "conquistou, roubou e submeteu" centenas de pequenas galáxias, pois existem alguns "imigrantes" evidentes em nossa galáxia, incluindo a segunda estrela mais brilhante no céu do norte, Arcturo (Gibson e Ibata 2007: 30). É amplamente aceito que o surgimento e expansão de um buraco negro pode levar ao ato de "comer" a matéria das estrelas e galáxias próximas. No entanto, a "capacidade de comer" dos buracos negros é muito exagerada na literatura popular. Nos sistemas de estrelas duplas ou nos sistemas de planetas estelares, também é possível observar uma forma de interação como a troca de energia e recursos.

- **Fatores externos como gatilhos de transformações** desempenham um grande papel, por exemplo, quando um grande objeto celeste passa perto de nuvens moleculares gigantes ou uma estrela explode, etc. isso pode iniciar o processo de formação de estrelas e galáxias (ou seja, disparar um processo de concentração de gás). As colisões entre corpos celestes podem formar novos objetos. Assim, supõe-se que a Lua tenha surgido como resultado de uma colisão de um grande objeto com a Terra. A onda de choque de uma supernova próxima pode ter sido um gatilho para o nascimento do Sol cerca de dois milhões de anos antes que seu colapso tivesse começado (ver Adushkin et al. 2008, 276; Bizzarro et al. 2007; Grinin 2017, 2018).

Assim, podemos formular a regra *dos fenômenos ou eventos geradores necessários para iniciar o processo evolutivo.* Muitas vezes, é necessário pressionar um gatilho para disparar uma transição de fase ou a transformação de um objeto. Por um lado, este último não funcionará sem a prontidão interna de um sistema, mas por outro - mesmo um alto nível de prontidão interna não pode iniciar o processo de transformação, como a pólvora não pode explodir sem fogo. Sem um gatilho, o sistema pode permanecer no estado de prontidão potencial para transformações por um longo tempo. Nesse caso, emergem análogos de sistemas típicos / reconhecidos evolucionários.

1.4. Multilinearidade

A multilinearidade é uma das características mais importantes da evolução. Infelizmente, ele não recebe atenção suficiente e há uma tendência de reduzir a evolução para uma única linha - aquela que produziu o mais alto nível de complexidade, que muitas vezes é interpretada como a principal linha de evolução. Contudo, em todos os estágios do desenvolvimento evolucionário, é possível encontrar uma interação de algumas linhas que podem ter futuros bastante diferentes. Em outras palavras, além da principal linha evolutiva, sempre é possível identificar várias linhas laterais. Em primeiro lugar, elas contribuem para a crescente diversidade; em segundo, elas permitem expandir o leque de oportunidades de pesquisa para passar para novos níveis de desenvolvimento; em terceiro, as linhas laterais podem entrar parcialmente na corrente evolutiva principal, enriquecendo-a. Muitas vezes lidamos com duas ou mais linhas de desenvolvimento coexistentes e comparáveis, cuja convergência pode levar a um avanço quantitativo e a um efeito sinérgico. Várias linhas de desenvolvimento podem se transformar umas nas outras. Em outros lugares, escrevemos muito sobre a questão da evolução social nesse contexto (ver, por exemplo, Grinin e Korotayev 2009; Grinin e Korotayev 2011; Bondarenko, Grinin e Korotayev 2011; Grinin 2011).

- **Formas clássicas e seus análogos.** As linhas principais e laterais da evolução podem ser consideradas em duas dimensões: 1) horizontal (no que diz respeito à complexidade e funções), 2) vertical (referente à versão que seria realizada posteriormente em fases evolutivas mais altas). Parece também possível falar sobre versões clássicas e seus análogos. Assim, várias formas de agregação e especialização de unicelulares podem ser consideradas análogos de multicelulares (ver Eskov 2006), enquanto várias organizações políticas não-estatais complexas podem ser consideradas versões análogas aos estados (ver Grinin e Korotayev 2006; Grinin e Korotayev 2009; Grinin e Korotayev 2009; Grinin 2011 para obter mais informações). Formas clássicas e seus análogos podem se transformar; no entanto, são apenas os análogos que tendem a se transformar em formas clássicas, e não o contrário (o último pode ser visto como uma adaptação forçada a mudanças acentuadas nas condições e, às vezes, até como uma degeneração direta).

- **Estrelas e nuvens moleculares: duas formas paralelas de existência de matéria cósmica.** Nesse sentido, podemos considerar estrelas e galáxias como a principal linha de evolução e as nuvens gigantes como suas linhas laterais; o primeiro pode ser indicado como “formas clássicas” e o segundo pode ser designado como “análogos”. Por um lado, essas formas realmente se transformam umas nas outras. Galáxias e estrelas emergem de nuvens moleculares gigantes, enquanto estrelas surgem através de explosões e podem se transformar em nuvens de poeira de gás ao descartar seu invólucro externo. Por outro lado, nuvens moleculares gigantes são capazes de se concentrar; a troca de energia ocorre dentro delas e, portanto, em termos de gravidade

> e complexidade estrutural, são bastante comparáveis às estrelas e galáxias. Elas também excedem as estrelas no nível de organização das partículas elementares, uma vez que as moléculas estão concentradas nas nuvens, enquanto as partículas elementares e os núcleos estão concentrados nas estrelas[12]. Além disso, as estrelas quando perdem a matéria e descartam seus invólucros (devido a uma explosão) passam para o estado de poeira de gás interestelar que se acumula em nuvens moleculares.[13]

Conclusão: A formação de várias linhas evolutivas no nível do micro-mundo

Evolução astrofísica e astroquímica. Quase desde o início do desenvolvimento do Universo (quando a temperatura atingiu milhares de Kelvin), a evolução química surge acompanhando uma evolução física e astrofísica. Evidentemente, a evolução química também ocorre dentro das estrelas com o surgimento de elementos mais pesados. No entanto, isso foi antes a formação da base para a evolução química, porque os processos químicos envolvem as reações que levam ao surgimento de novas substâncias. Tais processos prosseguem, antes de tudo, dentro das nuvens de poeira de gás, onde as moléculas emergem. Moléculas de hidrogênio são absolutamente predominantes quantitativamente; apesar disso, moléculas de água e algumas outras substâncias também surgiram. A evolução química continua também nos planetas (onde combina com a evolução geológica, ou melhor, planetária), bem como nos pequenos corpos celestes (asteróides e meteoritos). Ao mesmo tempo, nos planetas onde, devido ao vulcanismo, pressão e outros processos geológicos, as temperaturas podiam ser altas o suficiente, a atividade química diferiu significativamente da atividade nas nuvens frias.

Evolução química dentro da evolução cósmica. Seguindo Friedrich Engels (e sua "Dialética da Natureza" [Engels 1940]), os representantes do materialismo dialético afirmaram que a forma química de organização da matéria é evolutivamente mais alta que a física. No entanto, em contraste com as formas biológicas e sociais que, desde a sua origem, exibiam níveis de organização substancialmente mais altos, a forma química (que emergiu quase imediatamente após a forma física) não representou uma forma mais alta de evolução por um período bastante longo de tempo. Este não é o caso da evolução geológica (ou melhor, planetológica) que surgiu nos planetas há muito tempo e da evolução avançada (incluindo a química) através da formação de vários minerais e de condições de temperatura mais confortáveis para o desenvolvimento, bem como a formação de atmosferas e até de hidrosfera em alguns lugares (como em Marte). No entanto, o progresso evolutivo adicional se tornou possível apenas como uma preparação para a formação de condições apropriadas para a vida na Terra.

Isso não quer dizer que a evolução química não seja importante no quadro da evolução geral estelar e galáctica; no entanto, antes do surgimento de planetas semelhantes à Terra, as formas físicas e químicas de organização da matéria devem ser consideradas igualmente importantes; note também que eles se transformam constantemente um no outro (ver também Dobrotin 1983: 89)[14]. O desenvolvimento da evolução astroquímica não é limitado pela formação de moléculas não-orgânicas simples. Os processos de formação de moléculas prosseguem em direção à formação de substâncias orgânicas. Mais de cem tipos de molécu-

12 As moléculas também podem ser encontradas nas camadas periféricas de algumas estrelas, nas áreas com baixas temperaturas.

13 Em vários níveis de generalização, as nuvens de tamanho comparável com as estrelas são consideradas seus análogos, enquanto as maiores são análogas das galáxias.

14 De qualquer forma, é importante notar que as reações termonucleares fazem com que a evolução química da Galáxia prossiga em uma única direção, a saber, de elementos simples a complexos (Surdin e Lamzin, 1992). Isso também se refere à evolução em geral.

las orgânicas foram detectados no espaço (incluindo de 9 a 13 moléculas atômicas), inclusive o etanol e o aminoácido Glicina (veja Surdin 2001; Surdin e Lamzin 1992; Shklovskii 1978). Naturalmente, isso facilitou o surgimento da vida de uma maneira bastante significativa.

A pré-adaptação também se manifesta nas reações químicas de um tipo peculiar que prosseguem nas nuvens de poeira de gás "não da maneira usual, mas através de uma transição de mecânica quântica de sub-barreiras, que não requer muita energia cinética dos participantes da reação" (Surdin Lamzin 1992). Em outras palavras, a multilinearidade também é expressa no fato de que as reações químicas clássicas (que já poderiam ocorrer em alguns planetas) têm seus análogos. Como resultado, a multilinearidade da evolução torna-se ainda mais real no conjunto de avanços de suas várias linhas (químicas e geológicas), como aconteceu na Terra, o que lhe deu a oportunidade de passar para um novo nível evolutivo.

A formação de "pré-adaptações" como pontos de crescimento evolutivo futuro

Na era astro-galáctica, a forma química de desenvolvimento pode ser considerada uma "pré-adaptação" para novos níveis de evolução. Observemos que, em biologia, o termo "pré-adaptação" denota as adaptações que podem ser úteis em um ambiente diferente e dar vantagens significativas às espécies que as possuem[15] - e geralmente - para impulsionar a formação de novos táxons.

Dentro da estrutura da Macro-História, o princípio de "pré-adaptação" significa que, no nível em que uma pré-adaptação surge, ela geralmente desempenha papel insignificante; no entanto, em um novo nível evolutivo, essas "inovações" geralmente dão impulsos evolutivos. Respectivamente, os compostos químicos (como é comum nas pré-adaptações) não significam muito para a evolução cósmica; eles estavam "reservados" para revelar toda a sua importância no nível da evolução planetária. [16]

Gostaria de terminar este artigo com uma nota sobre mais uma peculiaridade das pré-adaptações. Condições adequadas são necessárias para a sua formação. Na evolução biológica, as pré-adaptações geralmente surgem em ambientes peculiares. Assim, supõe-se que a transformação das barbatanas dos peixes de barbatana carnuda (da qual os anfíbios descendem) em pernas primitivas ocorra no ambiente de águas rasas que frequentemente secam. De maneira semelhante, na evolução das estrelas-galáxias o surgimento de compostos químicos complexos pode ocorrer apenas dentro de certas estruturas de nuvens cósmicas que tornaram possível a sua existência, pois protegeram as moléculas da radiação cósmica.

Conclusão:

Assim, é importante resumir nossa abordagem que, em nossa opinião, é frutífera no campo da Macro-História, como em qualquer outra pesquisa sobre análogos evolutivos entre cosmologia, sociedade e mundo biológico.

Podemos ver diferentes mecanismos, tais como: catástrofes, autopreservação, interação com o meio ambiente, luta por recursos, formação de objetos individuais, formação das linhas principais e laterais, diversidade, seleção etc., que demonstram a semelhança das regras evolutivas e padrões em diferentes fases da Macro-História e em diferentes níveis de evolução. Infelizmente, não podemos prestar atenção suficiente a cada mecanismo e regra, porque para uma explicação detalhada seria necessário escrever um artigo especial.

Vale ressaltar que alguns autores consideram a seleção natural o principal e, às vezes, o único mecanismo evolutivo, que funciona não apenas no estágio biológico da Macro-História, mas também no estágio cosmológico. Sem dúvida, a seleção é importante e, juntamente com outros mecanismos evolutivos, pode fornecer insights da formação da estrutura do Universo. No entanto, como o leitor pode entender, consideramos o mecanismo de seleção apenas como um dos mais importantes para a cosmologia, mas de maneira

15 Essa capacidade onívora dos hominídeos permitiu sua transição para a caça em uma fase muito inicial da antropogênese.

16 Sobre pré-adaptações na megaevolução, ver também Grinin, Korotayev e Markov 2011: 159-160.

alguma o principal e, sobretudo, não o único.

No entanto, não se pode deixar de dar crédito a muitas hipóteses cosmológicas interessantes. Por exemplo, David Baker explora o mecanismo de seleção entre um enorme número de universos no “multiverso”. No entanto, seu algoritmo com relação à seleção de universos dificilmente poderia ser chamado propriamente de darwiniano. Ele prefere falar sobre a seleção evolucionária em geral - que não é a seleção dos mais aptos, mas a seleção daqueles capazes de evoluir - que é um conceito muito mais amplo que a seleção darwiniana. A ideia de que essa seleção não é darwiniana é confirmada se empregarmos as obras de Christian (2014) e Smolin (2008)[17].

Em conclusão, queremos repetir os objetivos do artigo. Primeiro, usamos uma narrativa histórica mostrando a origem e o desenvolvimento de modelos evolutivos gerais e, em seguida, explicando-os para dar uma idéia da formação da estrutura em larga escala do Universo.

Em segundo lugar, o objetivo era encontrar semelhanças evolutivas em diferentes níveis e usá-las para a análise da semelhança de regras e padrões evolutivos em diferentes sistemas.

Não tentamos apenas aplicar os princípios evolutivos já formulados de diferentes sistemas biológicos ou sociais complexos às questões cosmológicas. Este método pode estar errado, pois muitos desses princípios serão inadequados na cosmologia.

Em terceiro lugar, mas brevemente, algumas questões foram discutidas sobre análogos de funcionamento e desenvolvimento entre vários objetos e sistemas.

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17 Smolin frequentemente se refere ao princípio antrópico como uma idéia evolutiva muito importante, que não abordamos no artigo.

Toward a Big History Interpretation of Religion

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Abstract: The word "religion" refers to a wide range of phenomena ranging from Tibetan Buddhism to the Prosperity Gospel. As a result, religion has accrued a "bewildering variety of definitions". This essay, rather than asking the ontological question – "What kind of thing is religion?" – looks at religion epistemologically, asking what religion enables people to know. The resulting exploration suggests that religion is part of the process by which human groups come to know and adapt to the powerful, often-mysterious forces that produce awe and terror. By looking at how societies at different levels of social complexity have responded to the crises produced by these forces, the author suggests that the habits of mind that would become science and philosophy, as well as religion, evolved as the way those societies have adapted to existential crises, especially in times of rapid, widespread change.

Key Words: mental models, myth, ritual, hominin evolution, social complexity

Introduction

How should students of Big History approach religion? It sounds like a simple question, but little about religion is simple, even defining the word, as Wilfred Cantrell Smith pointed out a half century ago. The word, he notes, had generated "a bewildering variety of definitions" (1991/1962: 17). Among the dozens of definitions and more-general descriptions, religion has been called a "childhood neurosis" (Freud, 1989/1927); an "opiate of the people" (Marx, 1844); a "by-product of the misfiring of several [brain] modules" (Dawkins, 2006: 209); "a meaningful, all-pervasive order that embraces the world" (Assmann, 2001: 3); the source of moral behavior (Norenzyan, 2013; Stark, 2011); and a "disease of the human mind" (Russell, 1936). To add to the confusion, nearly all these descriptions seem valid from their author's points of view. *However*, if most of these descriptions are valid, then the really interesting question is: Can one gather all these fragments of the concept we call "religion" into a coherent, scientifically valid schema? That's the task I want to begin in this essay.

Before I do, however, it's important to take a look at two key problems that have made it so difficult to avoid this fragmentation of and confusion about religion as a concept. First, the dominant Western intellectual model of religion has taught scholars to think of religion in ways that are significantly different from the way people in other times and places have. Consider just three elements:

- Westerners think of religion as a set of beliefs and behaviors that are separate from ordinary life, mostly for the Sabbath and Holy Days (Winzeler, 2012). As satirist Tom Lehrer observes, "On Christmas Day you can't get sore./Your fellow man you must adore./There's time to rob him all the more/The other three hundred and sixty-four" (1959). On the other hand, in most times and places, religion is so deeply woven into everyday life that there isn't even a word for it (Nongbri, 2013).
- Westerners assume that religion demands the individual's belief in the literal truth of

mythology (e.g., Dennett, 2007). Yet, in other places and times, people were not concerned with whether members of the group believed their gods were true; what was important was participation in group rituals (Vásquez, 2011; Walton, 2006).

- Westerners think of religion as a set of things that act as agents in the world – *systems* of belief and practice (e.g., Durkheim, 1915), *institutions* (e.g., Dennett, 2006), and *forces* for good or evil (e.g., Stark, 2011; Harris, 2004). Until the Reformation, however, Western Europeans thought of religion as an attitude, a sense of inner piety that informed behavior (Harrison, 2015).

This dominant way of thinking doesn't create serious problems for scholars who are examining Western religions today. But when they are exploring the origins of religion, the application of today's atypical understanding to earlier times can drive even a first-class thinker such as Richard Dawkins to make questionable statements, such as his suggestion that religion "doesn't have a direct survival value of its own" (2006: 200), a suggestion I shall contradict repeatedly in this essay.

The second problem is the use of the word "religion". For one thing, the concept of religion was the creation of Western academics to indicate a class of phenomena that may not always fit together comfortably (Smith, 1991/1962). After all, the animism of Australian Aborigines is far different from Catholicism or Islam, and all of them are unlike Buddhism, Hinduism, or Daoism. Moreover, some religions, such as Christianity and Islam, posit a God who seems like a punishing father who exists outside the natural world, while others, such as Hinduism and Buddhism, identify God as the consciousness of which we are part; some religions teach a difficult ascetic path while others seem to function more like social clubs. To put them all together in the same linguistic bucket is to invite misunderstanding. As Smith puts it, "The phenomena that we call religious undoubtedly exist. Yet perhaps the notion that they constitute in themselves some distinctive entity is an unwarranted assumption" (1991/1962: 17). Is it any wonder that so much of the literature about religion – not all, but much – seems fragmented and confusing?

In this paper, I want to present the beginnings of an alternate model of religion avoiding this fragmentation and confusion by exploring religion *as part of an evolutionary process*. Creating such a model is a task I cannot hope to complete alone. It requires applying research from fields ranging from paleoanthropology and neuroscience to biosemiotics and complexity theory, and I bring only a limited knowledge of any of these fields. My purpose, then, is not to present a finished version of this model. Rather, I want to suggest what this model might be capable of so that others who find it interesting can refine and perfect it.

To develop such a preliminary version of this model, I want to explore five issues:

- Describe religion as an evolutionary process that integrates myth and ritual;
- Provide an overview of the conditions in which religion began to emerge as climate change drove our hominin ancestors from the East African rainforests;
- Speculate how myth developed as those ancestors learned to live in new and changing environments;
- Suggest how the need for stronger social bonds in far more open woodlands and savannahs might have led to proto-religious rituals and their integration with myth;
- Examine how religion can be treated as a wider process, which I call societal adaptive learning.

With all this in mind, let's begin with the hypothesis I intend to develop and examine as an alternative understanding of religion.

A Tentative Description of Religion

From my point of view, religion *uses myth and ritual to enable human groups to know and adapt to the powerful, often mysterious forces that evoke awe and terror*. These are the "powerful forces that permeate things but cannot ordinarily be seen" (Hayden, 2003: 57), the forces that generate birth and death, abundance and famine, the feeling of oneness with the Universe or the experience of being conquered and exiled. Religion has persisted for tens of thousands of years and continues to be universal in human societies, in spite of being costly in terms of time and energy, because it enabled our ancestors to struggle with these powerful forces, adapting to them in ways that produce all the "things" we think of as "religious" – priests, prayers, and rituals; theology, houses of worship, and religious hierarchies. All this suggests that religion enabled its practitioners to survive better than non-practitioners (Hayden, 2019).

While my focus is on *human* religion, like most evolutionary developments (Schwartz, 1999), human religion did not appear suddenly. Rather, a significant body of evidence suggests that the practices and feelings we associate with religion are deeply grounded in "proto-religious" behaviors, especially among large-brained mammals. Those behaviors include the burial rituals of elephants (Meredith, 2001), the insistence on fair treatment among primates (de Waals, 2014), or signs of proto-religious awe and ritualized behavior among chimpanzees (Turner, *et al*., 2018). My speculation is that, with changes in brain structure among our hominin ancestors, these proto-religious behaviors and feelings could have evolved over time into what would become a more recognizable human form. With the emergence of *Homo erectus*, 1.8 million years ago, a larger, more sophisticated brain may have led to early storytelling, and therefore myth-making, capabilities (Laughlin, *et al*., 1990; Donald, 1991; Newberg, et al., 2001; Everett, 2017)) and a far more corporate, mutually assisting sociality, likely with significant rituals (Turner, *et al*, 2018). Myth and ritual, I suggest, became increasingly integrated in Neanderthals and, perhaps, archaic *Homo sapiens*, whose sophisticated language added a powerful element to existing proto-religious behaviors.

What enabled these proto-religious behaviors to become religion, in the sense I am using the word, was the way the human brain structures conscious experience around a symbolic order. Scholars continue to argue over when this symbolic capability developed,[1] but dating its emergence seems far less important than the fact that human beings do order their perceptions of the world symbolically. In religion, elements of this symbolic order include what Roy Rappaport (1999) calls "Ultimate Sacred Postulates", cosmological axioms that cannot be proven, but are accepted as obviously true. In Judaism, the *Shema*, declaring the oneness and uniqueness of the Hebrew God, is such a cosmological axiom, as is the Nicene Creed in Christianity. Even the Newtonian worldview is symbolically ordered around cosmological axioms, such as the belief that the Universe is composed of separate, distinct things, or that it exists in four dimensions. I speculate that once the biological drive to tell stories about events around us (Laughlin, *et al*., 1990) and the hominin adaptation of primate ritualized behavior came together with the symbolic ordering of experience and mutually dependent social relationships, religion would have become all but inevitable.

Turning now to the climate change that drove our evolutionary ancestors out of the East African rainforests, perhaps five million years ago.

1 These estimates range from Robin Dunbar's (2016)30,000 years to my personal favorite, Brian Fagan's (2010) 70,000 years, and Merlin Donald's (1991) 125,000.

Out of the Rainforests

By five million years ago, climate change had dried out parts of the East African rainforests, eventually driving our evolutionary ancestors – the hominins[2] – down from the trees and into woodlands and savannahs (Fagan, 2004). That was a bold move that must have been made under terrible stress (Hayden, 2003). For more than 20 million years their ancestors, the great apes, had lived in those rainforests and evolved to meet its challenges, developing instincts and habits to deal with most of the experiences that threatened their survival. But now, the hominins were living in environments in which they had little experience. And because rapid climate change was continuing, the savannah they inhabited might shift to woodlands or even deserts, *in the lifetime of any of those hominins* (Fagan, 2010).

Given these conditions, they would face two key survival challenges. First, compared to their ancestors, they were strangers in strange lands and had not evolved to adapt to their new conditions. As a result, they faced new and unexpected dangers. The woodlands and savannahs they now inhabited had more scattered water supplies, and their plant foods were lower nutritive quality. As a result, they had to become more mobile and began eating meat, when it was available, more often (Fagan, 2004). To survive, they would almost certainly have had to evolve to have more memory and be more adventurous and innovative, developing new ways of perceiving the world that would allow them to take advantage of their new opportunities and avoid new threats.

These hominins would also need to cooperate more intensely. In the rainforests, the great apes lived in ample foliage, making it relatively easy to hide from predators, and allowing them to live relatively individualistic lives, with only a few close relationships (Turner, *et al*., 2018). Our hominin ancestors, however, lived largely on savannahs, in which they were far more exposed. So, as Robin Dunbar notes, "large social groups would . . . have been their main defence against predators on open pans and flood plains" (2016: 127). In addition, they would need to cooperate in order to scavenge and hunt for meat (Everett, 2017). As a result, they likely evolved to develop closer emotional ties and more intensely social groups.

The first of these challenges, as examined below, would lead to the ability to make myth; the second, to rituals. My basic assumption is that meeting both of these challenges was a matter of survival. There's been a great deal of discussion in scholarly literature about whether ritual or myth came first (e.g., Segal, 2015). I won't enter this debate. I find it far more important that these two adaptations to very different survival challenges *did* come together, and, in doing so, created such a powerful process for adaptation.

Rise of the Mythmaking Hominin

Our hominin ancestors would meet the first of these challenges in new and dangerous environments by entering an evolutionary path that would lead their descendants to become mythmakers. To present that path more clearly, I've broken my discussion into two sub-sections: First a look at the universal need of living things to know what they need to know in order to survive and how the human brain evolved in response to this need; then, an examination of the three questions the human brain must answer when faced with the powerful forces that led to mythmaking. I want to emphasize that many of the specifics that follow are speculative, based on the best available science.

Modeling reality

One challenge our hominin ancestors faced is

2 "Hominin" generally describes the evolutionary family of primates that separated, first, from the great apes of East Africa and, then, from the common ancestor of humans, chimpanzees, and bonobos. Its members may include australopithecines, *Homo erectus*, Neanderthals and *Homo sapiens*.

Species	Estimated Cranial Size	Date
Chimpanzee	350 cc	c. 5 million years ago
Australopithecus africanus	400 cc	c. 3.5 million years ago
Homo erectus	850 cc	c. 1.8 million years ago
Homo sapiens	1350 cc	c. 250,000 years ago

Table 1: Evolution of the Human Brain (Sarmiento, *et al.*, 2007)

universal. Like every species that evolved since life first appeared on Earth about four million years ago, they had to evolve ways *to know those things essential to their survival*. This challenge is universal because the world-as-it-is – that is, the world before our perception reduces it to manageable dimensions – is overwhelmingly abundant, a buzzing, formless mass of signals (James, 1950/1890), a field of many possible meanings that must be interpreted. In terms of sensual signals, a great deal more is going on in the world we walk through than what we consciously perceive. For example, a dog's sense of smell is thousands of times sharper than ours (Tyson, 2012). How might our perceptions of the world shift if we could smell as dogs do? Given the limited number of sensing organs any organism develops, *no* living thing can sense more than a "tiny subset of the real patterns in the world" (Dennett, 2017: 128). Members of any species can survive because natural selection has chosen the body structures that will enable them to perceive those patterns they *need* to recognize.

As a result, every species has had to reduce the field of *possibly* meaningful patterns into a *perceived* reality that will enable its members *to survive* (e.g., Hoffmeyer, 2008). Several thinkers have analyzed this need to reduce the world-as-it-is to a manageable scale. In his pioneering work, Jacob von Uexküll (2010/1934) called an animal's reduced field of perception its *Umwelt* – that is, the inner, subjective world. More recently, the Biogenetic Structuralists, most notably Charles Laughlin and Eugene d'Aquili, examined how our brains are structured to reduce the "operational environment" of the world-as-it-is to the individual's "cognized environment" (1974). I'll refer to this reduced field of continually changing images as our "perceptual model" of the world.

Any animal's perceptual model, then, enables it to experience the world as "a user-illusion brilliantly designed by evolution to fit [its] needs" (Dennett, 2017: 222). With many species of bat, for example, the perceptual model depends mostly on echolocation – sending out ultrasonic sound and creating a perceptual model of the environment from the echoes. Some mammals take advantage of a variety of senses to create their perceptual models. Dogs rely mostly on smell, but also on hearing and sight.

As they moved onto the woodlands and savannahs, our hominin ancestors would live a nomadic life in environments where food and water were more scattered and the environment was subject to change. One key evolutionary change that would enable their descendants to survive was a larger, more sophisticated brain (Table 1). The majority of that growth occurred in the neo-cortex and associated areas such as the hippocampus. This evolving hominin brain gave our ancestors increased memory, enhanced ability to understand the environment, and improved ability to plan and solve problems with its more powerful executive functions.[3] The larger brains of the australopithecines and *Homo erectus* were clearly evolving toward the more sophisticated perceptual model that culminated in *Homo sapiens*. That is, the brains of our evolutionary ancestors seemed to move toward the characteristic human perceptual model, transforming the superabundant world-as-it-is buzzing around them into coherent, story-like models

3 For a fuller discussion of the executive functions, see Donald, 2001.

(Laughlin, *et al*., 1990; Gazziniga, 2011).

Here, I use the word "story" in a specific way. Any story must reduce a fictional or real world of events and details into a coherent, meaningful structure (Boje, 2001). That's how people use the word when they ask a friend to give them the "real story" or a TV reporter tells viewers to stay tuned for the "whole story". That's also largely what our brains do *at an unconscious level* as they create the conscious images of the world that we experience. Neurobiologist Michael Gazzaniga (2011) describes this process as creating "make-sense stories".

Current paleoanthropology suggests that *Homo erectus* had a brain structure with the memory and problem-solving capability that might have supported an early version of the human, story-creating brain (Turner, *et al*., 2018; Donald, 1991; Laughlin and d'Aquili, 1974). I find that plausible. After all, *Homo erectus* migrated across Eurasia, adapting to both the Ice-Age forests of Europe and the jungles of India, and crossing significant bodies of water. The ability to make story-like models and plan more carefully would have made it far simpler to achieve these accomplishments, especially in what appear to be voyages of exploration to Crete, Flores in Indonesia, and Socotra, which is 150 miles from nearest land, the Horn of Africa (Everett, 2017). While other animals have made similar migrations, only humans had to create sophisticated artifacts, such as boats, to complete them.

It's tempting to speculate on when myth-making began to emerge. Bellah notes, for instance, that "something like religion might have developed" with *Homo erectus* and its increased memory and problem-solving ability (2011: xiv; see also Laughlin and d'Aquili, 1974; Donald, 1991; Newberg, *et al*., 2001). Laughlin and d'Aquili (1974), Bellah (2011), and Daniel Everett (2017) all take this argument one step further, suggesting that primitive language emerged with *Homo erectus*, which would have also made some form of verbal myth possible. However, because there simply is no way to verify such speculation, it's enough to note that the brain structures that enabled human religion were well developed by *Homo erectus* and that they would become more sophisticated, especially with the emergence of Neanderthals and archaic *Homo sapiens*, as natural selection continued to refine what would become the human story-creating brain.

Current neurobiology indicates today's *Homo sapiens* story-creating brain works like this: Faced with a new experience, the unconscious mind of any individual integrates a mélange of sense impression and memory and examines it all in light of existing *mental models* that encode our meaning structures. Then, it filters out any information that doesn't fit the meaning structures, creating a series of possible explanatory stories for any event. Finally, it settles on the scenario that seems most likely to ensure survival and delivers it to the conscious mind. All this happens in a fraction of a second (see Gazzaniga, 2011; Ramachandran, 2011). What makes this unique to human beings, as opposed, say, to the strategic behavior of carnivores such as tigers, is the way human mental models are symbolically coherent and are shaped by shared meaning structures, not just immediate survival needs.

Please note the difference between "perceptual model" and "mental model". A person's perceptual model is the parade of conscious images, which presents a simplified version of the superabundant world-as-it-is, so that he or she can act. When I look down a street here in Philadelphia, my unconscious mind filters out much of what is there so that I *can* see those things I need to survive. Mental models, on the other hand, present "inner mental replica[s] that [have] the same 'relation-structure' as the phenomenon that [they represent]" (Johnson-Laird, 1983: 11). Such models embody what any person learns that the world *should* or *should not* be like.

They reflect repeated experiences and thereby encode prejudgments about the world, as shaped by the symbolic order that the person accepts. What sort of people should I be afraid of? How should I respond to the U.S. flag? Should I trust people in authority, such as doctors and politicians? What sort of person should I fall in love with? These are some of the questions that anyone's mental models will answer. These models are enormously powerful because they enable us to "filter our ongoing perceptions and prejudge our experiences" (Siegel, 2010: 152), strongly shaping our perceptual models.

Three questions

With this process, the individual's unconscious mind creates its story-like perceptual model, which enables him or her to understand, consciously, what is going on. To do so, the unconscious mind must answer three critical questions:

1) What's happening?
2) How should I respond?
3) Why is it happening?

Whether confronting a lion on the savannahs of Kenya or a pedestrian darting out into traffic in London, the brain answers the first two questions almost instantaneously in the amygdala, which is intimately connected to memory, below the conscious level. The resulting perceptual models enable us to choose to fight or run away from the lion, or to stop suddenly for the pedestrian. People who can't answer these questions in a way that lets them succeed in the world are less likely to survive (Laughlin, *et al.*, 1990). Once again, the lion confronting a human likely has to answer the same questions; the human brain, however, will focus more intensely of the meaning structure encoded in its mental models.

The brain processes the third question a fraction of a second later, also in the amygdala. Anyone who's known a three-year old has experienced the terrible urgency of the word "why". The answers to this third question often contribute to the mental models that help determine a person's perceptual models, as the answer to "why" becomes effective in interpreting the world – that is, shaping the answers to the first two questions. Any person's mental models will also filter information that conflicts with a model out of that person's perceptual model, as the person tries to make sense out of a confusingly abundant world.

These questions can also be applied socially. When groups are faced with events that evoke awe or terror – a flood, for example, or an especially abundant harvest, their members will work together to answer these three questions: What is the nature of this event? How can they, as a group, best respond to it now and in the future? And what caused this event? I speculate that one source of religion was the cause-and-effect stories, mythic stories, that people have told to answer this third question since *Homo sapiens* developed the ability to perceive in a symbolically coherent way. Such mythic stories identify the forces of nature that create such events as spirits, ancestors, gods, or the One God, and may also record how they or their ancestors responded. The stories that enabled groups to survive these events most successfully were most likely to enter the group's mythology. What enabled those stories to work is the way that they provided metaphors for the forces of nature that caused the events, opening group members to ways of thinking about the events and creating shared memories about how the group had responded to them in the past (Campbell, 2004; Assmann, 2011). In this way, myth became an early human method for knowing about the natural forces that might pose existential threats and for surviving in a changing, often dangerous world.

This is my central objection to Atran's position (2002) that the mythical world is "supernatural" and "counterfactual". Yes, as Hayden (2018) speculates, many people almost certainly did believe their mythical gods and spirits were real. However, for any society as a whole, especially pre-literate societies, that mythological world could have created a way to explain, explore, and adapt to forces *that were very real parts of their natural world*. Poseidon represented the potentially overwhelming dangers of the sea, to which the seafaring Ancient Greeks had to respond. His presence in Greek mythology could remind people not only of its dangers, but also how others had met them, as in Homer's *Odyssey*, for example. Especially for pre-literate societies, the metaphor of gods or spirits was an effective way to understand they mysterious. If this analysis is accurate, myth is not merely a collection of "counterfactual" stories; it is often an essential guide to living successfully in the here and now (see Rue, 2005). Myth, and the ritual that brought groups together to remember and celebrate them, may well be how humans first came to know and adapt to such forces.

The importance of these mythic stories has recently been emphasized by the work of neurobiologists such as Andrew Newberg (2018) in the field of study he calls Neurotheology. By scanning the brains of people engaged in religious and spiritual activities such as prayer and meditation, Newberg and his associates have identified several brain circuits that allow people to experience God/gods, as existing in the world and open to relationships (Newberg and Waldman, 2009: 43). The issue here is not whether such circuits "prove" that God is real. Rather, it indicates the importance of being able to experience God/gods as immediate and real. From my perspective, the issue here is the need to be able to use the socially defined concept of God/gods as an exercise in social learning. One's conception of God/gods is the gateway to a variety of types of information about the forces that all of us have to confront, both individually and in groups (Campbell, 2004).

To understand how complex and pervasive religion as a process became, especially as human communities grew larger than hunter-gatherer bands, consider a few of the functions of myth, as people face powerful forces that could overwhelm them:

- First, it offers examples of how we can live our lives in harmony with those forces. On one hand, that means reconciling people to the very real horrors of life, including the realization that life lives on death (Campbell, 2004). In more mundane matters, Judaism gives us the graciousness to strangers of Abraham; Islam, the example of Mohammed as a just ruler; and Hinduism, Arjuna, the soldier caught between his duties as a soldier and the horror of having to fight friends and relatives.
- Second, it provides the stories that encode any culture's symbolic order, to which its young must be socialized (Luckmann, 1967). That symbolic order, encoded in myth, gives members the meaning structure that allows them to interpret the world similarly, to communicate, and to cooperate.
- Third, myth and the symbolic order it encodes enable people to shape their personal identities and recognize other group members from their behavior (Luckmann, 1967). The power of defining "Us" and "Them" through myth and a symbolic order is painfully clear today in the many nationalistic political parties taking power across the globe. Those parties may not be religious, but they use the tools that religion forged.

Moreover, as Jan Assmann notes, "We are what we remember" (2018: 75). The stories of myth give us easy-to-remember examples of much of what we must know to survive in complex social groups as the highly social animals that we are, especially when those myths are enacted in ritual. In fact, until the Axial Age, myth and ritual were one of the most powerful ways for societies to store collective knowledge (Assmann, 2011). This sort of mythic memory is essential to human identity. Americans whose "personal" mythology pictures the Civil War as an example of heroic loyalty and faith in the Southern way of life will understand their identities very differently from those whose personal mythology insists the war was the last gasp of American slavery. As a result of this sort of mythic memory, we can create a shared past and memory of our collective triumphs and humiliations, as well as the disasters that might lie ahead, and how we overcame and, in the future, can overcome them.

Finally, when circumstances change enough, the mythic tradition that enabled a society to thrive can begin to destroy it. At that point, people in that tradition must change it, if their society is to survive. This is essentially what happened in Israel after the destruction of the Temple in Jerusalem in 587 BCE. When the Babylonians took the elite of Israelite society into exile, and it seemed that their God, YHVH, had abandoned them, the culture was on the verge of collapse. To ward off that collapse, some members of the elite rewrote the Israelite mythology as a new sacred text that explained how the Israelite people had actually abandoned their God. The text promised that if they worshipped their God as the one true God, He would return His people to glory. With this reinterpreted myth, the Israelite culture would again thrive, as the basis for both Rabbinic Judaism and Christianity (Akenson, 2001). This is the process, which Wallace (1966) calls "revitalization movements", by which the old ways of living and governing society, grounded in its symbolic order, break down, so that society can evolve its myths to respond to new conditions or face its end (see also Assmann, 2011). It also reflects the way elites use religion to manipulate people in the societies they control (Hayden, 2018).

One last thing: People who engage these mythic capabilities can be driven either by community-oriented motives, such as love, or selfish ones, such as fear and the desire for control. We can see that, for example, in the Christian Bible, which begins with Jesus' preaching love, and ends with *Revelations* and its reflection of fear. Moreover, the Christianity of Paul is very different from that of Constantine because Paul was spreading the Word while Constantine was governing an empire. One reason there are so many different descriptions of religion is that a ruler and a mystic, a dirt-poor farmer and a wealthy merchant approach the powerful stories of myth from such different perspectives and often have different myths.

These few mythic functions might well be enough to explain why religion is such an important part of being human. But there's more. At the same time our evolutionary ancestors were learning to live in new environments, they also had to learn to meet another survival challenge – to live as intensely social animals.

The puzzle of social cohesion

Living in the savannah, and coming into frequent contact with large predators, demanded that our hominin ancestors become more intensely social. One survival strategy that would facilitate tighter social cohesion appears to have been ritualized behavior. The roots of that behavior seem to have emerged over the last 150 million years as some animals became more and more dependent on cooperation to survive. These "social animals" range from ants and bees to cockatoos, wolves, and chimpanzees. They often rear their young cooperatively, live with several generations in permanent settings, hunt and defend the group together, and rely on group learning. Social animals also have groups with defined roles and hierarchies. As a result, they need ways to communicate complex messages quickly and effectively and, in some animals, to make public displays of loyalty to ensure group cohesion (d'Aquili, *et al*., 1979).

Some ritualized behavior is almost entirely a matter of genetic programming. For instance, a butterfly, called the silver-washed fritillary, has a seven-step ritual: The male begins with a first signal, and the female makes a countersignal, through seven steps (d'Aquili , *et al*., 1979). While this "ritual" is fixed in the butterfly's genes, similar behavior patterns in birds and mammals, with more highly evolved brains, are often partially learned, as with the songs birds in some species sing to signal they are members of their specific groups.

The more complex the social group, the more important these ritualized behaviors became. Many mammals, wolves for instance, have highly complex group dynamics. Wolves within a pack can have different temperaments and roles; they cooperate in hunting and have social hierarchies. So, they need ways to communicate complex messages. In one ritualized pattern, the leader parades a bone in front of the pack, then drops it so the rest of the pack can inspect, and then ignore it (d'Aquili, *et al*., 1979: 84-5). Through this ritual, the leader can state his claim to leadership, and the other members can acknowledge it. As a result, social animals can communicate complex messages – "I am your leader/follower" or "I am approaching you not to hurt you but to negotiate sex" – *without verbal language*. They also enable group members to commit to the social hierarchy, as with wolves. Or build trust between members, as with primate grooming and human gossip (Dunbar, 2016).[4]

Most great apes and the species that descended from them are social animals, practicing a variety of ritualized behaviors. Some of those behaviors even suggest proto-religious feelings. Chimpanzees, for example, will gather in groups of about 50, and hoot, scream, and drum on old logs with sticks (Turner, *et al*., 2018: 110). The common rhythmic movement of this behavior enables the chimps to entrain their nervous systems – that is, to share the same neural patterns – creating a sense of group unity (Newberg, 2018; d'Aquili, *et al*., 1979). Jane Goodall also describes the "waterfall dance", where chimps stand near a powerful waterfall, apparently transfixed by it, swaying in rhythm and behaving with what seems like human wonder. "Perhaps, after all it is not so ridiculous," she observes, "to speculate as to whether chimpanzees might show precursors of religious behaviors" (quoted in Turner, *et al*., 2018: 114).

Our hominin ancestors had to become far more intensely social and dependent upon each other than chimpanzees. They had to do so because when they left the rainforests of East Africa, they moved into more dangerous environments. When they hunted or scavenged, they needed to protect each other from the large, dangerous predators of the savannah. To strengthen that cooperation, natural selection chose a wider palette of emotions, including key social emotions such as guilt and shame, starting about 3 million years ago, which may have become the "biologically-based propensities for human reliance on religion" (Turner, *et al*., 2018: 2). The changes in brain structure that resulted in these new emotions appear to also have made a suite of characteristics that we think of as human possible, including affection, responsibility, and the need for belonging (Hayden, 1993). With this wider palette of emotions, our hominin ancestors would likely have adapted primate ritualized behavior to develop proto-rituals that would have become more sophisticated with the emergence of new species, especially Neanderthals (Hayden, 2003). By the time *Homo sapiens* emerged, their coherent symbolic perceptual model would likely have allowed the sort of ritual that we recognize today.

Like the word "religion", the word "ritual" can be more than a little confusing. There are informal rituals, such as shaking hands; social rituals, such as a Japanese tea ceremony; political rituals, such as the Presidential Inauguration in the U.S.; and religious rituals, such as Catholic Mass or hunter-gatherer initiation ceremonies. While I want to focus on formal, religious rituals, it's worth noting that all rituals have important similarities. All of them enable participants to communicate complex messages, draw tentative conclusions about other participants, and, most important, create a sense of unity among participants (Rappaport, 1999; d'Aquili, *et al*., 1979).

4 For a fuller discussion of the pre-human origins of such "ritual" behavior, see d'Aquili, *et al*., 1979.

For more than a century, scholars have argued over whether myth or ritual came first in the evolution of religion (e.g., Bell, 1997; Segal, 2015). However, for the model of religion examined in this paper, the important issue is not which came first, but the power that resulted from myth and ritual becoming integrated in religion. Those religious rituals have generally become less emotionally intense and more cerebral over the last five or six thousand years, as larger, more complex societies developed strongly institutional religions in which priests replace shamans (Hayden, 2003). In hunter-gatherer and tribal societies, religious rituals evoked more primal emotions, often creating an ecstatic state by inflicting pain, the use of psychotropic drugs, or prolonged drumming, chanting, and dancing (Campbell, 1969). Much of this ritual behavior could lead to altered states of consciousness and mystical visions. Current neuroscience has examined how this ritual can also lead to a feeling of unity among participants, as those rituals enable them to resolve problems of "life and death, good and evil, quest and attainment, God and human being, that are present in mythic form" (d'Aquili and Newberg, 1999: 100). With the secret societies and ancestor cults of complex hunter-gatherer societies (Hayden, 2018) and, then, the emergence of writing and a professional priesthood in the early agricultural states, however, the intensity of rituals, which might include scarification or human sacrifice, lessened. I would suggest that one reason for this shift is that the powerful forces religion was confronting seems to have moved from facing the raw forces that threatened survival to issues of social control and justification of the state. In any case, even today, ritual can create a powerful sense of unity through passion in events such as Hitler's Nuremberg rallies or the anti-war rallies of the 1960s. Here, the religious nature of the rituals has become something quite different, but the neurobiology still seems to be the same.

Like the myth they often dramatize, rituals serve a variety of functions (Wallace 1966; Rappaport, 1999; Seligman *et al.,* 2008). For example, participation in a ritual signals a person's commitment to the group and teaches the young what it means to be a member. Rituals can also serve the needs of any group's elite, whether by justifying the inequalities of wealth and power that arose in post-forager societies or by enhancing the strong group loyalties that make it easier to motivate members against those outside it. They are also effective in enculturating the young to what it means to be a member (Luckmann, 1967). Key information communicated to the group through rituals can include: elements of group mythology and cosmology; the potentially overwhelming events group members experienced in the past and how they coped with them; and the power of feeling one with the group.

The last of these functions emphasizes Assmann's "We are what we remember". Rituals that are repeated regularly strengthen the neuronal connections in the brain, significantly strengthening any memory over time, thus giving them more power to shape the lives of participants (Newberg, 2019). Consider the Jewish ritual of the Pesach (Passover) *seder*. The *seder* ceremony is an annual discussion of the exodus from Egypt, as summarized by its ritual question, "Why is tonight different from all other nights?" It is different because it is the night set aside to retell the story of the exodus, with participants invited to experience the story *as if they were actually leaving Egypt*. In many ways, the exodus is the central myth of Judaism, and, in the Torah, God tells His people to remember its events on two occasions. The remembrance of this ritual not only enables Jews to self-identify in participating, but would be periodically re-enacted, as they came into a new land, became successful and then oppressed, and were thrown out. In this way, the *seder* became a yearly rehearsal for the next cycle (Assmann, 2018).

When myth and ritual came together in religion, they provided ways for people in their societies to remember and enact their symbolic orders, to commit to their groups and pass on knowledge of it. And when their worlds change so much that the old symbolic orders no longer work, religion, as a process, has repeatedly made a significant contribution to the process of cultural transformation. In the final section of this paper, I'd like to speculate how religion functions as part of a process I think of as societal adaptive learning, which makes this sort of cultural transformation possible.

Religion, cultural transformation, and societal adaptive learning

The concept of societal adaptive learning emerged as part of the the work I've done examining religion as a process. It offers a possible dynamic for what Wallace calls "revitalization movements". In his words,

> [R]eligious belief and practice always originate in situations of social and cultural stress and are, in fact, an effort on the stress-laden to construct a system of dogma, myth, and ritual which are internally coherent as well as true descriptions of a world system and which thus will serve as guides to efficient action. (1966: 30)

As Dmitri Bondarenko and I note, three periods of human history demonstrate this sort of social and religious transformation most intensely:

- The Neolithic Revolution (c. 11,000 years ago to 5,000 years ago), during which human communities underwent the transformation from forager bands, mostly egalitarian, nomadic groups of about 20 without hierarchy; to more sedentary transegalitarian, complex hunter-gatherer societies; to more complex city-states; and, eventually, to early agricultural states, such as Ancient Egypt or Shang China with cities of tens of thousands;
- The Axial Age (c. 800-200 BCE), during which the early agrarian state (c. 3000-800 BCE), with a god-like king, ruling through loyalty among his inner circle, became agrarian empires (200 BCE-1500 CE), as in the Roman Empire or Chinese Dynasties;
- Modernity (c. 1500 CE to the present), during which these empires may become a transnational, global system of national entities (Baskin and Bondarenko, 2014).

During each of these transformational periods, the societies experiencing this revitalization found their older, long-successful social structures breaking down and a new structure breaking forth (Assmann, 2011). However, the process by which these transformations occurred suggests that religion is only one of three habits of mind that human groups employ to make such transformations. Curiously, these three habits of mind suggest a group version of the three questions that human brains are structured to answer for us individually:

- What's happening? To answer this question, group members would have to observe the powerful forces in action, calculate their results if possible, and create a model for them. It would be oversimplifying to identify the group version of answering this question as "science", especially in the eyes of those who insist science must provide "reliable predictions in the form of a mathematical model" (Wootten, 2015:383). Yet, it does suggest the habit of mind, a systematic study of nature, at the heart of a scientific approach.
- How should we respond? As they developed a model of the force's actions, group members, especially those in leadership positions, would be likely to discuss their options for responding to those actions, implement the responses they found optimal, and go back to the first question to observe the results. These discussions seem to provide the habit of mind for what we think of as philosophy today.
- Why is it happening? Here, group members have to find the best ways of explaining forces that are both powerful and in many cases mysterious.

As noted earlier, until science and philosophy emerged as separate studies, the gods and spirits of myth, as representations of these forces, and the rituals that often enacted them, were effective in both explaining and remembering the effects of such forces. As a result, the need to answer this question on a group level may even be a neurological element in the origin of religion. It is, however, important to remember that the people creating these explanations were generally among the elite and were often politically motivated (Hayden, 2018), as in the choice of the Orthodox Christian Church in canonizing the four gospels and rejecting those of the Gnostics (Akenson, 1999; Pagles, 1979).

Because these three habits of mind inform each other in the process by which societies cope with powerful forces, I have come to think of them cumulatively as the process of societal adaptive learning.

The comparison of myth with science and philosophy has rich tradition, including such figures as J.G. Frazer, Claude Lévi-Strauss, and Karl Popper, in the discussion of science, and Paul Radin and Ernst Cassirer in philosophy.[5] However, to the best of my knowledge, no one else has suggested that myth, science, and philosophy are three components in the same process. I want to emphasize that even if this speculation is valid, any strict one-to-one examination of these questions to the three methods for responding to powerful forces will be misleading. After all, science often tries to determine how people should respond to these forces, and philosophy sometimes speculates on why they happened. Moreover, as we'll see, religion, science, and philosophy complement and provide feedback for each other. What I am trying to suggest is that religion does not stand alone; rather, it is one of three habits of mind that have enabled our species to cope with forces capable of overwhelming human groups, all of which seem to emerge from the structure of the human brain. This is the sort of provocative speculation that I found working with this model of religion can generate.

5 For an overview, see Segal, 2015.

What seems more certain is that all three types of knowledge were incorporated in religion in preliterate times. Writing emerged at the end of the 4th Century BCE in Sumeria and Egypt; it would continue to be used mostly by the government and commercial interests, only becoming culturally important early in the Axial Age, for instance, in Homer's epics or the early Israelite pre-biblical texts (Assmann, 2011). Because the habit of mind that we think of as science was initially fused with religion, the astronomy of Babylon was performed by its priests (Campbell, 2003), and in Egypt, "science and religion were intermingled" (Mancini, 2004: 31). Similarly, the Egyptian Pyramid Texts, one of the earliest religious text scholars are aware of (dated between 2400 and 2300 BCE), deal with philosophical questions such as "What is life on earth, how does it relate to time and the interrelationship of all things, what is death, what survives death" (Morrow, 2015: 13)?

Science and philosophy began to develop separately from religion in the Axial Age experiences in Greece, India, and China. In all three cases, these methodologies for understanding the powerful, mysterious forces these societies faced remained deeply interconnected. As an example of that interconnection, I want to examine the Greek Axial Age experience.[6] Mycenaean civilization had dominated Greece from the 14th Century until the middle of the half of the 12th Century BCE. It was ruled was by kings with strong religious duties (Burkert, 1985) who, as in other early agricultural states, governed through the loyalty of their inner circles. Mycenaean religion was built on the oral mythology that Hesiod and Homer would write down in the late 8th and early 7th Centuries. Mycenaean society seems to have been overwhelmed by a combination

6 The Chinese experience is also well documented. Interested readers can consult Robert Temple's *The Genius of China* (2007) on its science and Benjamin Schwartz's *The World of Thought in Ancient China* (1985)on its philosophy.

of factors that may have included climate change, natural disaster, internal hostilities, external threats or competition, and a degree of social complexity its social/economic structure could no longer support. By the end of the 12th Century, all of Greece had entered a period often referred to as a "dark age" (e.g., Cline, 2014).

The culture and political power of Greece would not begin to flourish again until Greek's Axial Age, which began in the late 8th Century and early 7th Century BCE. At that time, Homer and Hesiod were recording Greece's pre-axial oral mythic tradition in writing. This transformative period seemed to begin with a restatement of Greece's traditional religion, as it had evolved to face the challenges its society faced. Partly as a result, Hesiod's retelling of old myths suggests the overwhelming sense of chaos that people in early Axial Age Greece must have felt, as in the story of Uranus eating his children or the rape of Persephone. Homer's epics present an idealized version of the Bronze Age warrior and his dedication to honor as a way to live in harmony with the chaotic forces represented by the Greek gods (Campbell, 2015).

Myth and the symbolic order it encodes, as noted earlier, can help shape the behavior of people in any society. The writings of Homer are especially interesting in this respect. The *Iliad*, for instance, presents the small Greek polities, such as Mycenae, Sparta, and Ithaca, feuding like brothers, coming together to meet the challenge to their honor of the enemy in the East, Tory, and returning to their old ways. For about 300 years after the *Iliad* appeared in writing, the leaders of the most powerful *poleis*, especially Athens and Sparta, behaved exactly that way, feuding like brothers, until, in 490 and 480 BCE, Persia, *an enemy from the East*, invaded Greece. Like their counterparts in the *Iliad*, the Greeks would defeat their enemy, and then return to their brotherly fighting, leading to the devastation of the Peloponnesian Wars (434-404 BCE), reinforcing the earlier fears of chaos expressed in Hesiod.

This century of experiences threatened to overwhelm the more powerful cities throughout Greece. It was also a period of cultural efflorescence, especially in Athens, as Greek society sought to answer the three questions of societal adaptive learning. The Greek tragedies of Aeschylus (c. 525-456 BCE), Sophocles (c. 497-406 BCE), and Euripides (c. 472-406 BCE) explored what had happened, examining the chaos of the time *at a religious festival*, the Dionysia. These tragedies, moreover, were mostly reinterpretations of the mythology found in Hesiod and Homer. The *Orestia*, for example, examines the chaos that resulted from the Trojan War, especially Agamemnon's decision to sacrifice his daughter Iphigenia to the goddess Artemis. It was as if the society, as a whole, was saying, "We followed the ways prescribed in the stories of the gods, and what we got was chaos. What happened?" The society, as a whole, was asking the first of the three questions the individual human brain must answer when faced with a challenge.

This effort to answer the first question also took other forms. Even before the shocks of the 5th Century, some Greeks were looking to understand the world in new ways, growing from both the need to predict natural phenomena better in a society that increasingly profited from sea trade and the rejection of Greek myth. Starting with Thales (fl. 585), Greek natural philosophy, combining what we think of as philosophy and science, began by rejecting mythic explanations and looking, instead, for answers in nature, rather than the gods. Later, Pythagoras (fl. mid 6th Century) would find perfect harmony in mathematics, making it the basis of a school of mysticism. Early in the 5th Century, Heraclitus (fl. 500), who saw change as the fundamental reality, and Parmenides (fl. 480), who insisted that change was illogical, argued over the fundamental nature of reality. Later still , Leucippius (fl. 435) and Democritus (fl. 410) proposed that everything in the world was composed of tiny particles, atoms, which made the cosmos a lifeless machine (Lindberg, 2007).

All this work to understand the world of Ancient Greece would come together in the philosophy of Plato (427-348/47) and Aristotle (384-322), as a way of examining why these catastrophic events had occurred and how to respond to them. Jeremy Lent (2017) describes the emerging Greek worldview as "the divinity of reason". Having lived through the horrors of the Peloponnesian Wars, Plato proposed that a creative spirit, the Demiurge, had employed mathematics to impose the "order and rationality of the cosmos" on what had been chaos (Lindberg, 2007: 19). The chaos that Greece experienced was the result of people not using their rationality, and, instead, settling for mythic explanations which left them experiencing the "shadows" of the real, as he depicted in the Parable of the Cave in the *Republic*. Aristotle would then apply Plato's "divine" reason to explore areas ranging from biological diversity to tragedy (Bellah, 2011). The world was rational. Human beings created chaos because they would not allow the divine intellect of the "Unmoved Mover" to guide them.

Ultimately, these Axial Age adaptations were successful, allowing Greek society to meet the challenges of the forces of chaos that had challenged it and reestablish a sense of order. The troops of Alexander the Great would spread its symbolic order, Hellenism, all the way to India. Eventually, Rome and its empire would incorporate this sense of a rationally knowable world, and, through Rome it would influence Christianity and Modernity.

What fascinated Bondarenko and me was the way societal adaptive learning seemed to function so similarly in Modernity. Modernity began in society's response to a series of events that overwhelmed the social stability that had been created in Late Medieval Europe. Those events included the rise of a wealthy merchant class in the 13th and 14th centuries (Abu-Lughod, 1988); the bubonic plague (1340-1400), which killed off a third of the population in all social classes (McNeill, 1976); and a century and a half of religious wars, culminating in the Thirty Years War (1618-48). What would be needed was a new way of experiencing the world and a social order to replace feudalism, enabling Western society to reassert social order and manage the forces that had generated these events.

This social adaptation would begin as leading thinkers in Western Europe adapted old ideas taken from the religious mythology of the Late Medieval Church. First, both scientists and philosophers would take over the Church's view, beginning in the 12th Century, that nature was the purposeful creation of a loving God, a "second book" from which man could come to know God, as they did from the Bible (e.g., Gaukroger, 2006). This transformational process would also draw on the popular Christian myth of the Quest for the Holy Grail, a series of stories about King Arthur and his knights. In this myth, Arthur's kingdom can only be saved by the heroic efforts of Arthur's knights to find the Holy Grail, from which Jesus drank during the Last Supper. Modernity would transform these exemplars of Medieval devotion, on whom their society's salvation depended, into the great heroes of Modernity, scientists.

Much as Greek tragedy transformed the mythology of Hesiod and Homer, modern philosophy would reinterpret the Late Medieval mythology, especially in the work of Francis Bacon (1561-1626) and René Descartes (1595-1650). Bacon called for "a total reconstruction of science, the arts, and human knowledge" (Gillespie, 2009: 37), in order to know what Nature was and how it worked. He therefore promoted science as a quest by a new type of knight, the scientist, whose job was to torture nature in order to make it reveal its secrets. By discovering nature's hidden powers, these quest knights would master nature for the benefit of man and the salvation of society. Like Bacon, Descartes wanted mankind to use science to master an unruly and dangerous world, eliminating want and providing security. To achieve those ends, Descartes wanted to create a science of certainty through mathematics, which would enable the scientist to escape the distortions of the senses. By analyzing complex events in the world into their component elements, he believed that it would be possible to understand the laws by which God moved matter (e.g., Gaukroger, 2006). This would be possible because Descartes believed in a loving, reasonable God who would never deceive man. As a result, science would be able to fully explain God's world and how to perfect it (Gillespie, 2009). Descartes' philosophy would sit at the heart of the early modern worldview, as a way to return order to a world society that had descended into the chaos of war and unremitting change.

It was in the intellectual environment in which Descartes' philosophy evolved that Galileo and Newton would demonstrate the power of observing and mathematically modeling the world. Early modern science unfolded from thousands of years of earlier science, some would call it "proto-science" – from Ancient Greece, China, India, and Islam (e.g., Lindberg, 2007; Freely, 2012) – creating a backlog of knowledge without which early modern science would have been impossible. In these other societies, the *methodology* of science – defining what's happening through a systematic study of nature – appears to have been driven, initially, by the need of people in them to adapt significant challenges in nature and society and, also, by the prospects of wealth and power that technology promised.

Early modern science provided a powerful way of addressing the chaos caused by the collapse of feudal social structure and a century-and-a-half of religious war. It promised a way to manipulate a world that had seemed out of control and reorder society rationally. In many ways, Western science has accomplished this, although it has also caused a host of unexpected consequences, from global warming to the possibility of nuclear holocaust. We do live today in a world dominated by the results of science – from the computer I'm writing these words on, to the car I drive, to the pharmaceuticals capable of almost entirely wiping out contagious diseases. In less than 400 years, scientists have made it possible to vastly reduce poverty and the impact of disease. As Wooton notes (2015), science has accelerated the rate of knowledge acquisition by emphasizing the concept of "discovery", in realms that range from sub-atomic particles to the cosmos. In many ways, the early modern worldview culminated in science, just as Axial Age Greece and China tilted their forms of social adaptive learning toward philosophy (Baskin and Bondarenko, 2014). In this way, science would take over more and more of the functions associated with religion, especially after the findings of Lyell in geology and Darwin in evolution made the idea of a world without a God possible.

These summaries of how societal adaptive learning transformed Axial Age Greece and modern Europe are relatively brief. My intent was to make the case for the common origin and ongoing interrelationship between these three habits of mind for more deeply knowing the world. If this speculation is accurate, then it suggests some new avenues for both the study of all religion, science, and philosophy, both as separate phenomena and as complementary parts of societal adaptive learning.

Conclusions

I want to emphasize that I present this model of religion as a hypothesis, a first step that must be researched, tested, and further developed. Nonetheless, it does seem to possess several advantages, even in its present form. For example, the model offers a narrative to explain why religion can be validly viewed from so many different, sometimes contradictory positions. As we've seen, myth and ritual can serve functions ranging from the personal to the interpersonal to the societal. In addition, all these functions can be used for purposes that benefit the community, such as encouraging social cooperation and human kindness, or to increase personal wealth and power, such as enhancing a leader's ability to scapegoat "heretical" groups. As a result, thinkers focusing on one or two functions, enacted from community or personal purposes, can find a wide variety of valid ways of describing religion, ways that may even contradict each other. In this way, religion can be portrayed as a force that can drive both moral behavior (Stark, 2011) and war (Harris, 2004).

Moreover, this model makes it clear why religion is universal to human societies: Religion is the product of millions of years of natural selection choosing for qualities that addressed significant survival challenges: Myth, appears to have emerged with the increasingly more sophisticated brain that enabled our ancestors to perceive the world so that they could behave in more innovative ways in new environments, and human ritual seems to have emerged with the brain changes that enabled them to meet the need for stronger social cohesion. Religion is universal, then, because it combines the evolutionary responses to two critical survival challenges. This is a far more satisfying explanation of religion's universality than Dennett's suggestion (2006) that religion is based on a "Good Trick", an experiment that is rediscovered and found useful, or Dawkins' speculation (2006) that it reflects the misfiring of brain modules. Interpreted through this model, religion is, rather, a key part of how our species has survived.

For me, however, the most important advantage of the model I've been exploring is the way it embeds religion in the complex context of research in fields ranging from neuroanthropology and current evolutionary theory to complexity theory, biosemiotics, and cognitive science (see also William Grassie, 2010). Religion, as I hope I've demonstrated, evolved in response to fundamental challenges to our evolutionary ancestors and has become critical to our cultural survival. As a result, the more fully scholars can understand the nature of being human from a cross-disciplinary position, the better they can expect to understand religion, not merely as systems of belief and practice or as institutions, but as the process by which our species has risen to meet a series of powerful existential challenges. And, in our world today, what sorts of understanding could be more important?

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Marine Resources and Prehistoric Adaptations: A Review of Trekking the Shore

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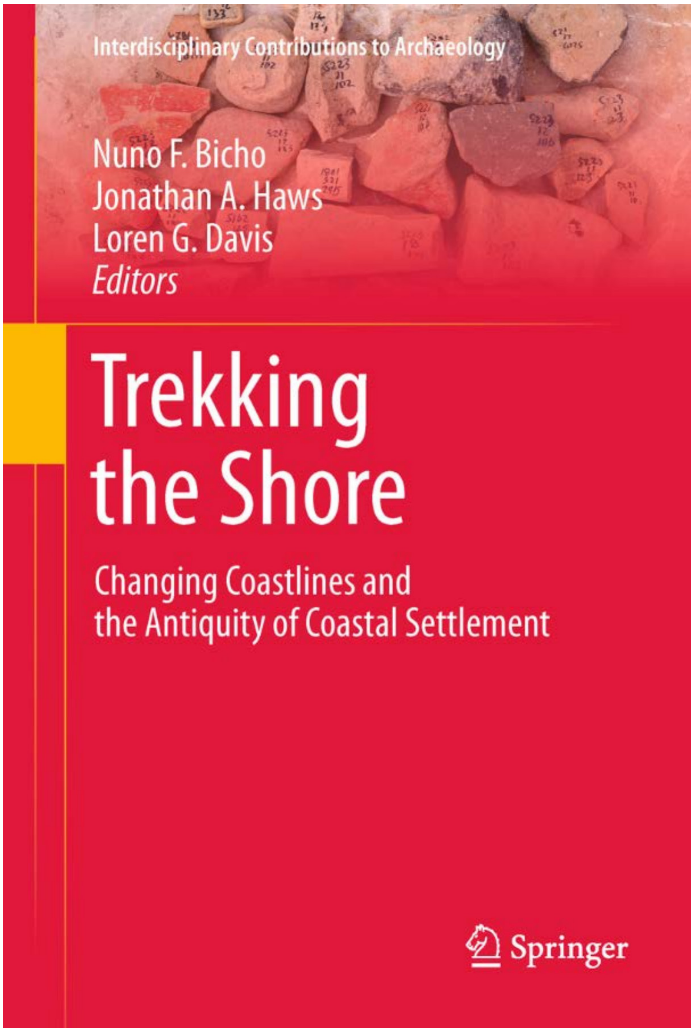
In the premier number of *Journal of Island & Coastal Archaeology*, Erlandson and Fitzpatrick (2006) note that coastal, maritime, and island environments were long considered "relatively peripheral" for the study of human prehistory. Lifeways study was biased toward "hunting of large land mammals" as primary and "agriculture . . . at the root of all human civilization." But recent studies have shown such coastal and marine environments are "increasingly relevant to a variety of important anthropological and historical topics," including the "antiquity of coastal adaptations and maritime migrations" and "the development of specialized maritime technologies and capabilities." Deacon and Deacon (1999), for instance have pointed to extensive use of maritime food resources in South Africa during the early emergence of *Homo sapiens* (c. 200,000 BCE), while several studies have explored maritime navigation (Clark 1991, Irwin 1992, Howe 2003) that made possible migrations from Island Southeast Asia to the most remote areas of Oceania.

Given increased attention to marine resources and evidence of prehistoric migration along continental margins, the time was right for *Trekking the Shore: Changing Coastlines and the Antiquity of Coastal Settlement* (2011), a collection of twenty studies by forty anthropologists, archaeologists, biologists, botanists, geographers, and field specialists.

Ground was prepared for the volume by two conference symposia (2006, 2008). Their emphases include coastal resources in human evolution, the



Trekking the Shore (2011), edited by Nuno Bicho *et al*, provides exhaustive surveys of selected coastal regions, detailing the role of marine resources in human evolution, prehistoric migration, and creative human adaptation stemming from the reliability and richness of marine, estuarial, lacustrine, and riverine environments.
Image source

role of coastal environments in prehistoric human settlement, and the interplay of human presence along continental margins with sea level changes during eras of glaciation and sea-level change. The result is a thorough scholarly survey of the field to date, each study featuring an exhaustive list of references.

A striking example of the importance of marine food resources has emerged in connection with the long presence (200,000 to 100,000 BP) of early *Homo sapiens* in South Africa. The human body does not produce polyunsaturated fatty acids—docosahex acid (DHA) and arachninoid acid (AA); these are produced by aquatic animals and plants. Various studies have linked these to human brain and retinal development during this extended period of continuous reliance on marine food sources. A second recognition centers on the now accepted coastal route of migration out of Africa following coastlines of South Asia (The Southern Dispersal) and recent discoveries pointing to a west coast route for humans entering the New World from Asia (The Coastal Route). These now preferred migration routes have focused anthropological attention on ocean coasts worldwide.

Trekking the Shore is organized in two parts: I. North America and Eurasia, and II. South America, Africa, and Oceania. This organization, as noted by the editors, is "based on latitude," though they are seemingly unaware that this treatment is synchronic rather than diachronic: latitude does not reveal a logic inherent in the subject and, in fact, veers away from the "trekking" of the title which suggests a movement, a continuity, an order, a chronology that is distinctly missing in the volume.

Seven studies (Nos 1 to 7) summarize the evidence for a Pacific coast route for humans entering the Americas. This route has emerged not only from fossil and genetic evidence of human coastal settlement at numerous sites from southeastern Alaska to Patagonia, but also from recognition that the previously preferred route of entry into North America through an interior "ice-free corridor" is no longer viable either ecologically or chronologically. The focus on Eurasia in five studies (Nos. 8 to 12) has, among other recognitions, extended the reliance on marine resources to earlier migrants out of Africa. Neanderthals, now recognized as probable descendants of *Home erectus,* who migrated out of Africa up to two million years ago, learned to exploit marine resources in Eurasia while *Homo sapiens* were developing similar skills in South Africa.

Three studies (Nos. 13-15) assemble evidence from Ecuador, Argentina, and Chile for varying kinds of reliance on marine resources, focusing attention on both the west coast entry of humans into the Americas and their subsequent adaptation to inland riverine environments. Three studies focusing on Africa, one from Morocco (No. 16) and two from South Africa, (Nos. 17-18) suggest a much more extensive use of coastal resources along ten thousand miles of African coastlines, studies of which are not included. The final two studies (Nos. 19 and 20) focus on extensive evidence for coastal settlement along the eastern coast of Australia—a region of substantial population density and thus most thoroughly excavated.

Investigation of coastal sites occupied by *Homo sapiens* provides much though not necessarily complete evidence for human adaptation to marine migration and settlement. A notable contrast is evident when comparing adaptation at diverse times and places. In a survey of west coast sites of North and South America, Willis and Des Lauriers (2011) summarize technological findings from *On Your Knees Cave* in Alaska to Indian Sands (Oregon), Daisy Cave (California), Ring Site (Peru) to Monte Verde III (Chile). These date after 11,000 BP, though Monte Verde shows occupation three thousand years earlier. In every case tool assemblages have turned up that include lithic remnants related to seafood harvesting, generally fashioned from local rocks. While occasional tools associated with inland faunal hunting show up, the primary adaptation along the Pacific coast is oriented toward exploitation of marine resources.

A distinct contrast is evident from South African sites where extensive excavations have been undertaken at Blombos Cave, Pinnacle Point, and more than a score of early habitation sites. Evidence dates much earlier, to the time of *Homo sapiens* emergence as a cognitively competent hominid, 200 to 100 thousand years BP (Marean 2011). Evidence of material culture includes beads, decoration with ochre, and pigment experimentation, with very limited seafood hunting tools. Adaptation to the coastal environment is almost exclusively found in middens that indicate extensive and continuous shellfish exploitation that requires gathering rather than hunting. At this early stage of *Homo sapiens'* development, humans appear to have been foragers rather than active fishers armed with hunting weapons. At much later dates and sites distant from Africa, evidence of coastal adaptation includes not only shellfish middens but also marine exploitation tool assemblies, not only down the west coast of the Americas, but also coastal sites for instance in Portugal (Haws et al, 2011) and the Russian Far East adjacent to the Sea of Okhotsk and Sea of Japan (Tabarev 2011).

Notably missing from *Trekking the Shore* are surveys of coastal life and adaptation in South and East Asia, the vast region of Island Southeast Asia, and Oceania—the latter two perhaps more dependent on marine food resources than regions covered in the book. The book, however, runs to a substantial 496 pages; additional coverage would have required a second volume. Taken together, these studies provide detailed and thorough analysis of coastal life at many locations around the planet, but the editorial organization into discrete regions—classified by latitude—with little connective commentary mirrors the knowledge departmentalization endemic to academia—in this case a kind of siloized geoanthropology. Big historians are regularly confronted with such silos from which they must extract details and patterns, then organize them according to chronology. This is the contribution of big history to knowledge: the molding of knowledge fragments into a continuous narrative.

With these limitations noted, the volume is important for the sheer scope of material assembled. Following up on the references for each chapter—often more than a hundred—is a formidable task, but the reward is that many references provide the connective narrative; one simply has to search it out. However, one would have hoped the editors had provided a synthesizing introduction that would move the separate essays into a more comprehensive history of human migration which, as noted, is implied in the "trekking" of the title.

From this perspective, it is worth noting that a continuous narrative of prehistoric human migration has yet to be written. One reason is clear: attempting to bring order to migration through the interior spaces of the continents, especially the vast reaches of inland Africa and Eurasia, seems out of reach. But coastal migration is another story. Continental margins may be riddled with bays and estuaries, temporary glacial blockage and torrential rivers, formidable cliffs and crashing surf, but they are continuous, passable by detour, and on calmer coasts, amenable to casual beachcombing. Of the many ways that prehistoric humans peopled the planet, *Trekking the Shore* points to the only continuous and certain route whereby *Homo sapiens* migrated from the most remote region of Africa, the southern cape, to equally remote lands end half a world away, the wind-blown mountainous terrain of Patagonia. That story is told elsewhere in this issue.

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A Cosmological Crisis?: A Review of Nasser Zakariya, *The Final Story: Science, Myth, and Beginnings*

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In *Maps of Time*, David Christian describes the narrative of Big History as "a modern 'Dreaming' – a coherent account of how we were created and how we fit into the scheme of things."[1] Yet, he adds more recently, that narrative "is far from complete, and . . . may need to incorporate the insights of older origin stories about how to live well and how to live sustainably."[2] The discussion of this narrative and how to strengthen it has swirled through every IBHA conference since the first, in 2012. More recently, it was the subject of a special issue of the *IBHA Journal*. For anyone who wants to understand this discussion more fully, I can't recommend Nasser Zakariya's *A Final Story* highly enough.

In his book, Zakariya explores the history of our origin story. (Like most writers on the subject, Zakariya refers to is as a "cosmology," which I'll be using in this essay.) He begins with the natural historians of the first half of the nineteenth century, who applied the growing body of scientific knowledge to construct a world history, intellectual pioneers such as John Herschel and Mary Sommerville. By the end of that century, the gallery of contributors reads like a Who's Who of progressive scientific thought, including Comte and Lord Kelvin, Julian Huxley and Einstein, E.O. Wilson and Carl Sagan. Zakariya tells the story behind the story with a wide-view, sometimes-critical perspective. For example, he documents the limitations of the scientific materialism at the heart of the evolutionary epic and the all-but-inevitable confusions that emerged in the attempts of Sagan or Neil deGrasse Tyson to popularize its complex scientific issues on TV.

Zakariya's treatment is solid, so much so that, rather than selectively explore parts of his book, I recommend letting *A Final Story* speak for itself. However, reading the book, I was struck by the need to clarify the concept of a "cosmology," especially for those of us, who, like Christian, want to develop a narrative that can meet the needs of people across the globe in the 21st Century. To do so, we need to understand the functions that cosmologies have always fulfilled and present the Big History cosmology in a way that is both accessible and acceptable. Otherwise, we could craft a story that will only work for ourselves.

At first look, this confusion seems to be a classic case of dueling definitions. From a scientific, Western outlook, cosmology is "the science of the origin and evolution of our Universe."[3] Yet, the word can also have a more mythic meaning, as in Joseph Campbell's definition, "an image of the cosmos that will . . . explain everything that you come into contact with in the universe around you."[4] Zakariya's book is largely about current attempts to bridge these definitions, as when Wilson insists that this "evolutionary epic is probably the best myth we will ever have."[5]

Similarly, Christian presents a more mythic version of Big History's scientific cosmology:

> a shared map of understanding that shows members of the community their place in a rich, beautiful, and sometimes terrifying universe: *This* is what you are; *this* is where you came from; *this* is who existed before you were born; *this* is the whole thing of which you are a small part; *these* are the responsibilities and challenges of living in a community of others like yourself.[6]

The key difference between these two definitions is not the story they tell, but the way that story is interpreted. Proponents of the scientific cosmology focus on the literal truth of their narrative; so, as Zakariya points out, they often present the Big-Bang-to-the-present narrative as superior to older cosmologies because it is based on fact, images of our Universe and mathematical computations, rather than mythic fictions. Ironically, astrophysicist Pedro Ferreira undercuts this claim when he notes, "Maybe more than in any other field of physics, *cosmologists construct fantasy worlds* which they hope may have some bearing on what we observe."[7] For proponents of a more mythic cosmology, the narrative is *a way of examining society and how we are to live in it*. Since the time of Ancient Egypt and Sumer, cosmologies applied the order that observers found in the skies to society. I'd suggest that these cosmologies reflect the symbolic orders with which members of any society approach their worlds, including their interpretations of the skies, in a way that enables them to apply that order, with its underlying assumptions, to their societies. As John Lundwall points out, cosmologies are epistemological, teaching members of any society how to know their worlds.[8]

For this reason, cosmologies can have survival value, especially when societies face existential crises, as our global society does today. For example, c. 576 BCE, the Assyrians conquered Judah (the southern Israelite kingdom), destroyed Solomon's Temple, and exiled much of its elite to Babylon. A similar conquest a century-and-a-half earlier had destroyed Israel (the northern kingdom). Yet, instead of accepting that their God had forsaken them, as people in most contemporary societies would have,[9] the society's elite reinvented its cosmology, by editing its mythic texts, so that their One God had not abandoned them, but was *punishing them* for not worshipping Him alone.[10] This interpretation would sit at the heart of their cosmology and His Chosen People's covenant with the One True God, which taught them that their God was so powerful that He could use the Israelites' greatest enemies as tools to enforce His covenant with them. In many ways, then the Hebrew Bible would function as an Israelite Big History, from God's creation of the world to the return from Babylonian exile. It allowed these Israelites to learn a different way of thinking about the world, developing a strong sense of responsibility in situations where they might seem victimized and providing many of the fundamental assumptions that would enable them to survive repeated pogroms and expulsions.

The same sort of reinterpretation would occur early in Modernity, leading to the West's current scientific cosmology. For the West, the existential crisis would combine the collapse of the feudal system after the Black Death, where about a half of its population died between 1347 and 1351, and the horror of a century-and-a-half of religious war, where Protestants and Catholics slaughtered each other to prove who knew the proper way to worship the Prince of Peace[11]. The two foremost reinterpreters were Francis Bacon and René Descartes. In response to these wars, both sought to create a form of science that would produce peace, order, and certainty.

This reinterpretation would integrate elements of Christian thought into the discoveries of early scientists such as Kepler, Copernicus, and Galileo. Copernicus described it as a "Clockwork Universe," and Galileo concluded that God had created the world as a "Second Book," written in the language of mathematics.[12] This image of the Universe as a machine became so firmly fixed in this emerging cosmology that the philosophy of Descartes and the physics of Newton would combine to picture our world as composed of dead, passive matter moving deterministically under the influence of Universal Laws of Nature. And because these laws were created by God, He was the source of everything that happened.

What Bacon and Descartes would do was to reinterpret key elements of Christian thought as a grounding for this emerging understanding of the cosmos. Bacon drew on the Arthurian quest myth, where the king's knights would sacrifice their lives to find the Holy Grail – the cup from which Jesus last drank – in order to save their society. For Bacon, the scientist would act as the quest knight and save the war-torn society of Western Europe, transforming it into an earthly Paradise.[13] To do so, Bacon also drew on the Christian understanding of divinity as an intellectual, masculine God, as opposed to the superstitious Earth Mother goddess of "pagans." So, scientists would "torture" Nature into revealing her secrets so that humans could exercise their intellects and reconstruct the world to produce a new world ordered for our benefit.[14] Bacon's myth provided the fantasy of order and control that Western Europe desperately needed, after a century-and-a-half of religious warfare.

Descartes drew on the Church's teachings that God was a rational creator who wanted man to understand his creation. For Descartes, science should discover the truth about our world, focusing on what the scientist could know with certainty.[15] In his efforts to do so, he would divide the world into passive matter, subject to God's Laws of Nature, and human mind. Most of the world, as passive matter, was therefore available for humans, through the power of their minds, to transform society as they learned more about these Laws of Nature. Combined with Bacon's philosophy, Cartesian thought provided the symbolic order that could promise the peace and certainty those who'd lived through the religious wars so desperately desired. Moreover, this cosmology justified the political system, as the ruler of Hobbes' *Leviathan* became the social equivalent of God, the ultimate cause of all events and the protector of the people, who, knowing they would be protected, could be as passive as Descartes' dead matter.[16]

This cosmology proved remarkably successful. With it, scientists could work hand-in-hand with the increasingly powerful commercial class. Just as Bacon had suggested, scientists revealed Nature's secrets, and, with the machine technology that became possible, the commercial class remade society. Largely because of this cosmology, food production has increased geometrically, contagious disease has largely been eliminated, and literacy rates have skyrocketed. Combined with the successes of science, especially in the discoveries of Lyle in Geology and Darwin in Evolution, God became a hypothesis that people could do without. And without God, the Western cosmology would increasingly become dominated by scientific materialism. The role of God would be replaced, first, by "Nature," whose now-anonymous laws moved all living things into action, and, then, by the Market and Adam Smith's Invisible Hand.[17]

And that is largely the cosmology of scientific materialism, Wilson's evolutionary epic, which rules today. For me, the problem with this cosmology – the problem that Zakariya points to over and over – isn't the story it tells. As long as we acknowledge that the story is a model – our best guess given what we know today – rather than the "truth," the story of the Big-Bang-to-the-present can serve the purposes that cosmologies have throughout human history. The problem is the often-unacknowledged assumptions built into the narrative, which, in many ways, have created existential challenges as great as those that precipitated the creation of this cosmology,[18] including global warming and the possibility of a mass extinction of life on Earth.

Ironically, thirty years ago, the same science that Sagan celebrated in his 1980 TV series *Cosmos*, was predicting that global warming would be generating the sort of dramatic events we've been experiencing over the last year. Except that the intensity of global warming's effects has outstripped those predictions. And, yet, while scientists, who learned their style of knowing the world from the current cosmology, have been creating a series of technologies to ameliorate those effects, only a relative few of those technologies have been widely implemented, and the use of fossil fuels, the deforestation of the Amazon, and the consumption of animal protein, all of which scientists agree are making extreme warming more likely, are all increasing. I'm convinced that one of the major factors that has enabled the politicians and corporate executives, who had the power to make the changes that likely would have reduced the danger to all of us to ignore those decades-old warnings, is almost certainly the very cosmology that Sagan's *Cosmos* celebrated.

In this way, the same cosmology that has taught us in the West how to map the heavens, send people to walk on the moon, and double human life expectancy may well have increased the likelihood of the most extreme events resulting from global warming. How all this happened demands a much longer explanation than I can even begin to give in this book review. People who would like to examine it in depth would do well to read Latour's *Facing Gaia.* But one element of it is central for those of us who believe that the Big History origin story can become an effective cosmology for the twenty-first century.

Grounding this narrative in scientific materialism seems to have created a mindset that treats the world around us as a cornucopia to be exploited without considering the consequences. Remember, any cosmology will provide people in its society a way to think about everything in the world around them. The cosmological narrative as told through scientific materialism insists that our world is composed of independent "things," chunks of passive, dead matter, responding deterministically to the universal Laws of Nature. Only human mind has agency in this world. And the task of the scientist is to torture nature until she reveals her secrets so that we humans can rebuild the world for our purposes.

So, if the concept of cosmologies I've been examining is accurate, then we would expect corporate managers and executives to behave exactly as they have. After all, the cosmology of scientific materialism views the world as a collection of separate things that exist so that we humans can use them for our own ends. Moreover, they are distinct and come together only under the pressure of outside forces. How then can we expect people who accept this cosmology to think in terms of the highly interdependent processes, such as the damage that logging in the Amazon does to the Earth's ability to process CO_2? If we want people throughout our economic systems to understand the complex processes that are making global warming look increasingly dangerous, we need a better version of our cosmology.

The point I want to make is that for those of us in IBHA, who believe that our origin story *can* be a cosmology for the 21st Century, exploring how best to present this narrative is one of the most important things we can do, as members of the organization. Fortunately (or unfortunately if you prefer), the summer of 2019 has made the urgency of acting to mitigate global warming unavoidable. How, then, can we present our narrative in a way that will encourage people to think in ways that will avoid the pitfalls that the scientific materialist narrative has created?

This question deserves a far longer answer than I can provide here. But one possibility has already received some attention. The approach here is to replace the assumptions of scientific materialism with those of the worldview that has been emerging through most of the 20th Century. This worldview sees the world as far more interconnected, full of agents that are continually changing to adapt to shifts in their environments, always with the possibility that even the smallest change can set off a cascade of adaptation.[19] Because it is so full of agency and interconnection, it is a world where the future is constrained, rather than determined by the past.

My hope is that we in Big History will begin a far more rigorous discussion of our origin story/ cosmology and how it can evolve to best serve its purpose. In a way, Zakariya's title thus seems ironic: For as the conditions in our world shift, so must our cosmology, suggesting that *A Final Story* is really impossible. For anyone who wants to participate in this discussion, Zakariya's book provides the solid historical background that can help us examine whether it does make sense to replace the assumptions of scientific materialism with those of the new model. Too much is at stake, for us and our grandchildren, to turn away from this task.

Endnotes

[1]David Christian, *Maps of Time: An Introduction to Big History*, (Berkeley, CA: University of California Press, 2004), 3.

[2] David Christian, *Origin Story: A Big History of Everything* (New York: Little, Brown and Co, 2018), ix-x.

[3]Pedro G. Ferreira, *The State of the Universe: A Primer in Modern Cosmology* (London: Orion Books, 2007), 13.

[4]Joseph Campbell, *Pathways to Bliss: Mythology and Personal Transformation* (Novato, CA: New World Library, 2004), 8.

[5]E.O. Wilson, as quoted in Nasser Zakariya, *A Final Story: Science, Myth & Beginnings (*Chicago: University of Chicago Press, 2017), 300.

[6]Christian, *Origin Story*, 8 (author's emphases).

[7]Ferreira, *The State of the Universe*, 10 (my emphasis).

[8]John Knight Lundwall, *Mythos and Cosmos: Mind and Meaning in the Oral Age* (Pleasant Grove, UT: C&L Press, 2015).

[9]Jean Bottéro, *Religion in Ancient Mesopotamia*, trans., Terresa Lavender Fagan (Chicago: University of Chicago Press, 2001).

[10]Donald Harman Akenson, *Surpassing Wonder: The Invention of the Bible and the Talmuds* (Chicago: University of Chicago Press, 2001).

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[15]Gillespie, *The Theological Origins of Modernity*; Toulmin, *Cosmopolis*.

[16] Toulmin, *Cosmopolis*; Bruno Latour, *Facing Gaia: Eight Lectures on the New Climate Regime*, trans., Catherine Porter (Cambridge: Polity Press, 2017).

[17] Latour, *Facing Gaia.*

[18]Mary Midgely, *Science and Poetry* (London: Routledge, 2001); Latour, *Facing Gaia*; Lisa H. Sideris, *Consecrating Science: Wonder, Knowledge, and the Natural World* (Oakland, CA: University of California Press, 2017).

[19] Two of the most interesting treatments of this new worldview are those of Nobel Laureate in Physics Robert Laughlin's *A Different Universe: Reinventing Physics from the Bottom Down* (New York: Perseus Books, 2005), and astrophysicist Lee Smolin's *The Life of the Cosmos (New York: Oxford University Press, 1997)*. Both Sideris' *Consecrating Science* and Latour's *Facing Gaia* explore some of the possibilities of applying this worldview to the cosmological narrative.