On Trends and Periods in Big History

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Citation | Aunger, R. (2024). On Trends and Periods in Big History.
Journal of Big History, VII(2); 29–42.
DOI | https://doi.org/10.22339/jbh.v7i2.7204

Abstract: Over nearly fifty years, Big History has evolved as an interdisciplinary approach, connecting cosmic, geological, biological, and cultural phenomena into a unified narrative of increasing complexity. This paper critically examines various theoretical frameworks within Big History, focusing on their scientific soundness. While progress has been made, challenges persist in establishing a theoretical core and achieving consensus. Commonalities exist, such as the recognition of a trend toward increasing complexity, the division into temporal eras and periods, and the acknowledgment of unique dynamics defining these phases. However, a consensus on the best foundational principles and canonical periods remains elusive. The paper suggests three strategies for theory development: employing cross-disciplinary theories, generalizing discipline-specific theories, or inventing novel theories. Each approach requires further refinement and empirical testing to contribute to consensus building. Big History is argued to have utility based on its ability to contextualize events within a broader framework, but more ambitious rationales and empirical work may be necessary for skeptical audiences. Despite ongoing theoretical debates, immediate progress can be achieved through empirical endeavors, contributing to the discipline's reputation.

1. Introduction

Several major philosophies of history can be identified in terms of the kinds of patterns of events they expect: a linear trend toward some objective (examples include St Augustine, Aquinas, Leibniz, Comte, Morgan), a series of repeating cycles (think of Thucydides, Ibn Khaldun, Vico, Spengler, Toynbee, Turchin), a 'dialectic' or repetition with progression (represented by Hegel, Marx), or random (i.e., just 'one damn thing after another'). Most Big Historians align with the 'dialectic' school – that there are features of history which repeat, but within an overall trend, typically seen as an increase in complexity.

In this view, the repetitive aspects of history allow one to break time into units, variously called 'eras', 'phases', 'periods' or similar. (I will prefer 'periods' going forward.) Big Historical periods have been identified using a variety of techniques, including leaps in the flow rates of free energy through relevant structures (Chaisson, 2001); changes in the way information can be stored and manipulated (DNA, brains, and artefacts (Sagan, 1977); or consistency with a mathematical temporal pattern (Panov, 2005). This paper seeks to find the strongest grounds for making such divisions for Big History as a whole (i.e., history since the Big Bang), together with the strongest theoretical foundation for describing the overall trend within which these divisions occur. The means used to find these theories will be to compare existing approaches using standard criteria of scientific strength. I will then suggest ways forward for the discipline consonant with an ambition to make it more scientific. First, a bit of background.

2. Background

2.1 Trend Theories

Why should there be a 'grand narrative' or overarching trend to history? What dynamic unifies the whole story? What makes history teleological – that is, in seeming quest of some objective? Most Big Historians see the grand historical trend as leading to phenomena of increasing complexity (however that is measured). This of course flies in the face of the thermodynamic imperative for the heat-death of the universe. We need an explanation for how Big History counteracts this cosmological principle, or adoption of another criterion besides complexity to define the Big Trend.

2.2 Periodization

It is philosophically possible to claim that all of history is just one long trend – for example, of increases in structures of maximal complexity – and that no clear breaks are real. It may be true that the processes working to produce these structures operate differently in the domains we call physics, biology and sociology, but these are ephemeral compared to the consistency with which events have unfolded since the beginning of time. However, it seems unfruitful to treat all of time and space as 'one big thing'. It has proven difficult to explain human social life using principles from physics, for example, which is why academic disciplines have split up their domains of explanation: one theory simply isn't big enough to encompass all phenomena from molecules to mankind. So it would seem periods are inevitable – especially for Big History.

A particular problem has been to rigorously identify the time-slots into which different periods of Big History fall, analogous to the periods into which historians have traditionally split up time since the invention of writing (the standard scope of history as an academic discipline) – that is, the equivalents of periods such as the Renaissance and Anthropocene. Hence, the search for the 'right' set of periods has become of central importance to Big History as an intellectual project. A rigorous periodization requires that causal mechanisms be found to explain how periods come about, and have the characteristics that they do (Aunger, 2007a). That is, we require an explanation of how periods arise.

A second question concerns when these periods occur. A common viewpoint is that periods recur with some pattern – often with accelerating regularity.[i] A second option is irregular periods. Christian, for example, chose a suite of events that occurred without apparent temporal regularity (Christian, 2008). In either case, understanding what circumstances precede the arrival of a new period needs investigation.

A third question concerns how many periods? Christian originally identified eight 'thresholds' (Christian, 2004). Others have suggested 12 periods (Hoggard, in press), 19 (Panov, 2005), 28 (Modis, 2002), etc. Is this just a question of how closely one is looking at history or a reflection of something more profound? Certainly the lack of consensus around this crucial issue (e.g., there is almost no overlap between the lists of Panov and Modis, despite both nominating many periods (Korotayev & Eurasian, 2018)) threatens the discipline's scientific credibility.

Finally, the why question. This is typically answered using the trend dynamic. But a number of Big History scholars also describe types of periods, some of which are more significant, 'major', or meaningful, than others (e.g., (Henriques & Volk, 2023; Grinin, in press). Obvious examples could be those periods that introduce new kinds of dynamics – such as the move from non-life to life, or individual life to social life – or differences in the scale of operation (e.g., from cosmological to earthly). For example, Henriques and Volk distinguish between 'level' and 'realm' transitions, where the former merely aggregates previously independent entities (e.g., atoms into complex molecules), whereas the latter bring about new kinds of dynamics (e.g., the origin of life) (Henriques & Volk, 2023).

2.3 Comparison criteria

We can compare approaches to these questions for their scientific value based on a number of well-recognized features of scientific theories.[ii] Such criteria of scientific 'strength' include:

- **Parsimony/Comprehensiveness**: Parsimony and comprehensiveness are related concepts – parsimony (also known as Occam's razor) being the quality of being able to explain a broad range of phenomena using relatively few principles and assumptions (compared to alternative explanations), and comprehensiveness in the present context implying that an approach is able to address the full range of phenomena included in Big History as a discipline (typically taken to start with the Big Bang and to end with contemporary human social history). As I will only be considering comprehensive approaches (see below), parsimony becomes the relevant criterion here.

- **Testability**: Theories from which empirically testable hypotheses can be derived are preferred. Particularly appreciated are those hypotheses which can, if proven, discriminate between competing approaches making somewhat different claims (Popper, 1962).

- **External validity**: External validity refers to the extent to which an approach's theoretical foundations are consilient with those of neighbouring sciences – that is, it relies on principles that do not clash in their implications with those processes at scales 'above' and 'below' those being explained (Feyerabend, 1975). I will consider the approaches covered here to have good external validity if they make reference to concepts or theories from disciplines of good standing.

- **Identification of Natural Kinds**: The concept of 'natural kinds' refers to categories of objects or phenomena that have an inherent nature or essence, leading to certain common properties or characteristics that distinguish them from other categories, and which define the fundamental units of some discipline (Quine, 1969; Griffiths, 1999; Griffiths, 1999). Examples include atoms (for physics), genes/species (for biology), and personalities (for psychology). A scientific discipline that successfully identifies a natural kind demonstrates a higher level of scientific rigor and tends to be more productive or progressive. For instance, in biology, the discovery of DNA led to the entirely new subfield of genetics being developed, leading to powerful new technologies.

3. The Approaches

I now move to comparing the candidate approaches. My analysis will exclude those approaches that do not seek to explain the distinguishing features of Big History: its historical scope and an attempt to provide a scientifically meaningful 'story' about that full scope. That is, I will exclude approaches that either deal with only a subset of eras covered by Big History (e.g., (Gehrels, 2017; Quaedackers, 2019; Torday, 2019)), or that don't make an explicit claim about long-term (inter-period) trend dynamics (e.g., (Delsemme, 1998)), or periodization (Constructal Theory (Bejan, 2016)), or both (e.g., the 'curve-fitting school' (Korotayev & Eurasian, 2018; Kurzweil, 2005; Modis, 2002; Panov, 2005), Hoggard, in press). [iii]

The candidate approaches having both an explanatory process underlying Big Historical periodization and a trend trajectory include (in historical order):

- the Self-organising Universe (Jantsch, 1980)
- the 'Grand Unified Narrative' (Christian, 1991; Christian, 2004)
- Cosmic Evolution (Chaisson, 2001; Chaisson, 2005)
- Perasmology (Aunger, 2007b; Aunger, 2007a)
- Extended evolution (LePoire, 2016)
- the 'Grand Sequence' (or 'Big History 2.0') (Volk, 2020; Henriques & Volk, 2023)
- Mega Evolution (Grinin, in press)

I will first describe each approach, briefly, in turn, and then move to the actual comparison. [iv]

3.1 Self-organising universe

Jantsch was an early advocate of the concept of 'cosmic evolution', which he saw as the history of events stemming from the dynamic processes initiated by the Big Bang, up to and including human civilization (Jantsch, 1980). While Jantsch didn't introduce novel mathematical models, he skillfully combined theories such as non-equilibrium thermodynamics, dissipative structures (a theory originally developed by Ilya Prigogine), and self-organisation to provide a framework for understanding the evolution of complex systems. He argued that once self-organization occurred at a certain level of complexity, it established relatively stable patterns of organization (which he called 'regimes') that persisted for some time. A regime involves a cycle of dynamics, driven by growth towards the limits of environmental capacity at a given level of complexity, followed potentially by collapse, reorganization, or the discovery of new resources. Complexity arises from energy gradients propelling non-equilibrium thermodynamic systems through processes of dissipative self-organization. He thought that energy, information, organization, and the environment all work in harmony to structure regimes, both during the physical development of the cosmos and in the evolution of life on planets like Earth.

One of the distinctive features of his approach was his idea of the concurrent co-evolution of both 'micro' and 'macro' structures. This means that self-organizing aggregations occur simultaneously at both small and large scales, brought about by various processes linking them. For example, gravitational forces simultaneously cause the clustering of atoms at micro-scale, but also into stars and planets at macro-scale, while life forms self-organize into ecosystems (micro-scale) and planetary Gaia (macro-scale).

3.2 Grand Unified Narrative

Christian's approach is to provide a 'grand unified narrative' that gets more deeply to human origins, to a complete explanation of where we come from (in causal terms). He outlines a broad periodization of 'Big History' with eight 'thresholds' or 'moments of change' that mark major shifts which have shaped the course of history and which provide a structured framework for dividing the history of the cosmos into meaningful stages (i.e., the Big Bang, star formation, complex chemicals, formation of planets, origin of life, culture, agriculture, modern life). These thresholds also mark significant shifts in the degree and forms of complexity at different scales that have occurred over billions of years.

As the framework which originally defined the field of Big History, it enjoys a special place in this field, and has been adopted by many as the proper approach to its content. Acolytes include Spier, who has very similar list of periods (cosmic, planetary, organic and human or cultural), but adds a 'Goldilocks Principle' (Spier, 2015). The Goldilocks Principle is that each threshold is preceded by a confluence of preconditions that establish a ready moment for the innovation to arise. What these conditions are depends on the level of complexity under consideration. Humans, for instance, cannot live below or above certain temperatures, and require sufficient air pressure, oxygen, food and water. Popularizations such as (Christian, 2018; Brown, 2012; Ferrone, 2021; Villmoare, 2023) have also appeared, indicating the high level of appeal of this approach.

3.3 Cosmic Evolution

Another of the most admired and widely used frameworks is that of 'Cosmic Evolution' (Chaisson, 2001), which makes use of the concept of energy flow through open, thermodynamic systems, including galaxies, stars, planets, life, and societies, to describe the subject matter of Big History. Chaisson uses increases in 'energy rate density' (the amount of free energy flowing per second through a gram of the most complex structure in existence at the time, measured in ergs (Chaisson, 2001)) as the metric of complexity. Transitions in the level of this value have produced, in turn, particles, galaxies, stars, planets, complex life, and human culture.

3.4 Perasmology

Perasmology, or the science of 'transitions', is the name given by Aunger to an approach based in non-equilibrium thermodynamics (like Jantsch) and Cosmic Evolution. Also featured is a generalization of the 'major transitions in evolution' (Maynard Smith & Szathmary, 1995), which covered biological and cultural processes, into what are called Non-Equilibrium Steady State Transitions, or NESSTs. NESSTs describe the internal dynamics of a transition to a new period, while the level of thermodynamic disequilibrium (measured via energy flow density) gauges a system's degree of complexity, as the theory of trend. NESSTs, as a more expansive use of the major transition idea, argue that there must first be an innovation in energy capture and flow, leading to the development of a novel kind of structure, which is then consolidated by novel control mechanisms arising in the new organisation to ensure its resilience and longevity. This sequence repeats to initiate a new period, with the consequence of a new kind of structure arising that has greater complexity than anything previously existing. Periods can be of varying length, with a trend toward an increase in the gap-time between periods during the cosmological era, but a decrease in gap-times during subsequent eras.

3.5 Extended evolution

LePoire has also argued that Big History takes place in two distinct phases: a cosmological phase, with a focus at the scale of the universe, during which transitions between periods occurred more slowly with time, followed by a second phase, with a focus only on earthly events, during which transitions occur with increasing frequency (LePoire, 2016). During the first phase, standard thermodynamical principles explain why transitions occur. But the second phase requires a different kind of explanation. LePoire argues that a good way to understand the mechanics of Big Historical dynamics in the second phase is via the use of complex adaptive systems models. Reorganizations arise to maintain a sudden increase in energy flows in these adaptive systems, leading to more complex organisations – a process he calls 'extended evolution'. LePoire more recently has argued that there are four necessary aspects to such a transition: use of a new energy source, an innovative information processing mechanism, (re)organization, and a new relationship to the environment (as a source of resources and a sink for wastes) (LePoire, 2023). Transitions arise when the existing complex adaptive system reaches an environmental capacity bound (LePoire, in press). LePoire argues that novel information storage and transmission systems occur first, enabling the subsequent development of new, more complex structures that can capture more energy (e.g., through photosynthesis) (LePoire, in press). A period of relative stability or smooth growth follows each transition.

He also distinguishes between eras (cosmic development, terrestrial life, complex ecologies, evolution of humans/intelligence and agriculture/civilization) and periods (not his terminology) (LePoire, in press). For example, periods within the most recent era include the invention of tools, plant domestication, evolution of chiefdoms, etc. Further, he notes that the duration of each of the nominated periods during this phase is roughly one third that of the previous period. A different but constant temporal relationship also exists between eras (each occurring 1,000,000 times slower or 1000 times faster over time, for cosmological or other eras, respectively), meaning that there should be roughly six periods per era.

3.6 Grand Sequence approach

Henriques and Volk also distinguish between periods (which they call 'levels'), and eras (called 'dynamical realms') (Volk, 2017; Henriques & Volk, 2023). A term of art associated with this approach, combogenesis, is an evolutionary step in which new organisations ('levels') are created, possessed of new relations among its elements achieved through combination and integration processes. Previously independent entities merge, with the structures of earlier transitions nested within them (Volk, 2017). Volk argues there have been twelve events of combogenesis in Big History, constituting a Grand Sequence: quanta, nucleons, atomic nuclei, atoms, molecules, prokaryotic cells, eukaryotic cells, multicellular organisms, social groups, tribes, agrovillages, and geopolitical states (Volk, 2017).

Within the Grand Sequence, four different eras can also be identified, each of which arise from a novel form of evolutionary dynamic (which they call a 'PVSR-dynamic', or form of Darwinian algorithm): Matter (physical laws), Life (biological evolution), Mind (psychological evolution) and Culture (cultural evolution). [v] They acknowledge that the initial, cosmological transitions didn't exhibit such evolutionary dynamics, which remains more applicable to those occurring since the rise of life. The jumps to new eras seem to these authors to be more dramatic and significant than the mere accumulation of through combogenesis, characteristic of jumps to new periods.

3.7 Mega Evolution

Leonid Grinin in recent work presents 'Mega Evolution' as an approach centred around ten 'phases' in Big History, five of which are major (Inflationary, Star-galaxy, Geological, Biological and Social), alternating with five 'transitional' (Pre-stellar, Planetary, Chemical, Biosocial and Anthropogenesis) phases; the latter are introduced to make it clearer how phenomena move from one level of organisation to the next higher level of complexity (Grinin, in press). Such increases are presumed to occur through an evolutionary process of search among alternative options. Some of these searches are successful, but do not lead to further complexification (e.g., the social insects are considered an early successful transition to social life, but a phylogenetic dead-end), while others become part of the main line of development of the Big History narrative, and become the building-blocks for later advances in complexity. Each transitional phase can be considered a precondition or pre-adaptation to the movement to the major phase. The existence of evolutionary dead-ends (in terms of further increases in complexity) shows that search and trial-and-error experimentation is required to reach a new major phase.

4. Comparing approaches

The approaches I have covered from the Big History literature are quite different in their theoretical claims, sets of periods, and other features. Nevertheless, they can be compared using the criteria outlined in the introduction to this paper (Table 1).

4.1 Self-organising Universe

Jantsch's approach was the first of several to rely on an 'extended' notion of evolution to cover the entire range of Big Historical phenomena. However, it is unique in its reliance on self-organisation as the primary mechanism inducing transitions to new periods. [vi] Jantsch's attempt to make specific links between macro- and micro-scale processes is also unique among Big History approaches. Jantsch was keen to combine a number of then-fashionable theories (self-organisation, non-equilibrium thermodynamics, dissipative structures), but this means that parsimony is low (although it does mean he brought in considerations of energy, structure and information, which would prove prescient). Because these theories are also non-disciplinary (i.e., applicable to a broad range of phenomena), they need specification to become empirically relevant, and don't make reference to the dominant theories in the disciplines allied to Big History, so external validity is also lower than it could be. The identification of periods as regimes can be considered a form of natural kind, however. It is interesting that none of the defining aspects of Jantsch's approach have been taken up by others in the intervening half-century, although his emphasis on evolution, energy, information and identification of transformative events remain central issues.

4.2 Grand Unified Narrative

The choice of Christian's thresholds seems to have been made primarily based on their educational, not scientific, value (Spier, 2022). Further, the causal model explaining how such negentropic events occur in the first place remains vague. Christian makes use of Spier's notion of 'Goldilocks conditions', or a 'just right' set of variables that allow a sudden increase in the complexity of material structures. For example, new technologies, increasing population pressure and warmer climates made Transition 7, to agriculture, possible. But why this particular confluence of factors is 'just right' to produce that threshold remains unclear, and different sets of factors are postulated to be responsible for other thresholds. This approach is thus quite weak on theoretical foundations (i.e., external validity) for both periodization and trend. (Though, to be fair, this approach is couched in a traditional history-as-one-of-the-humanities framework, not history-as-science paradigm, and therefore does not subject itself to the kind of criticism delivered here.) It also does not make a lot of claims about the causes of specific events which are different from those derived by the respective disciplines themselves, and so does not seem to be empirically productive (i.e., lead to novel testable propositions). It is more about the 'vision' provided from the large-scale viewpoint afforded by Big History.

4.3 Cosmic Evolution

The energy flow density metric has achieved near-universal adoption as a measure of complexity among Big Historical approaches. Parsimony and external validity are high, as Cosmic Evolution relies on a few principles from fundamental physics. Nomination of periods comes strictly from perception of a significant increase in energy flow density. So empirically, there must be a significant rise in this variable with each transition, a claim which has been contested by some ((LePoire, in press; Solis, 2023)). Nevertheless, this means testability is clear and straightforward. These are all major advantages of this approach.

However, the approach is unusual in not postulating specific mechanisms of transition, nor any internal structure to transitions themselves. There is little in the way of description of the mechanisms leading up to, nor producing, a transition to a new period, and no identification of a natural kind unit. Instead, there is a continuously varying metric, the rate of energy flow density, at the foundation of this approach. Indeed, there are few other scientific claims associated with it.

4.4 Perasmology

The reliance on repeating NESSTs to define periods has a number of scientific advantages. First, it identifies a strong candidate for a natural kind: NESSTs themselves, which have specific characteristics. This should make Perasmology empirically productive, in the sense that the approach makes specific claims about what kinds of mechanisms operate within each transition, and the order in which they must take place (i.e., energy innovation before structure, and structure before information/control). This facilitates the development of testable predictions about the contextual and causal processes in operation during each transition. It can also be expected that there are distinct phases within each period – a beginning during which the transition occurs, followed by a period of relative stability until the next transition (thanks to the existence of new control mechanisms) – a prediction which can also be tested.

Chaisson convinced many early on that energy flow density was the go-to metric for defining progress in Big History. Others have suggested that information processing is also an important consideration (Hookes, 2011; Solis, 2018). As with several other contenders, but not Cosmic Evolution, Perasmology puts both energy and information (captured in the form of new structures and control mechanisms) together in its definition of Big Historical transitions. However, it is not as parsimonious as some other approaches, as it is based on one theory (non-equilibrium thermodynamics) to explain trend, and another (macro-evolution) to explain periods. These are, however, the dominant theories in their respective disciplines, so external validity can be considered strong.

4.5 Extended evolution

Breaking Big History into two very different phases, each of which follows different kinds of dynamics, but with a continuous underlying trend (in terms of energy flows), is distinctive. However, because this move requires making reference to two very different theoretical foundations, the approach is not as parsimonious as some others.

Further, complex adaptive systems, based in cybernetics, is a modelling approach that has been applied to phenomena from widely different disciplines, from physics to biology and sociology. This makes it powerful, but also generic. This is also unusual, because most other Big History approaches typically derive from discipline-specific theories. This reduces external validity in a standard sense as there is no clear external discipline to which the approach refers. On the other hand, the applicability of cybernetics to such a range of disciplines might suggest that it more easily covers a broad range of the phenomena included in Big History (although LePoire does not apply it to the cosmological or geological eras). The generality of complex adaptive systems models, and lack of any instructions for how they might be applied in Big History, leaves the idea of an ‘evolutionary transition’ as a quite weak natural kind for this approach.

The reasons why each period is only one third the duration of its predecessor (or why there is a 1000 fold reduction in intervals between earthly eras with time) are not made clear (except that these relationships have figured in the curve-fitting work of several previous scholars). Neither are we told why it is important that periodization display such a regularity. The commitment to these patterns seems to derive from an appreciation of this prior work, and an as-yet unfulfilled quest to explain such a regularity of periods.

4.6 Grand Sequence

Combogenesis is somewhat similar in nature to the structuration step in the major transitions of Perasmology, but does not include the energy-based stimulus nor information-based control steps. This leaves the concept lacking a causal engine producing new periods. The combogenesis concept also lacks reference to any particular discipline or theory, and so has low external validity. The reliance on the Darwinian algorithm (which Henriques and Volk call 'PVSR dynamics') also weakens external validity (see Discussion below). They also do not identify a process link between their periods and eras ('levels' and 'realms'). That is, how do new PVSR dynamics, when they arise, feed into the combogenesis meant to be responsible for each new period? This leaves the two kinds of processes unrelated, which reduces parsimony. There are, however, claims made about the nested nature of structures resulting from a given sequence of combogensis events which could be tested, as could whether the dynamics of any new realm fulfill the strictures of a PVSR process (i.e., show variation, diversity and inheritance).

4.7 Mega Evolution

Mega Evolution doesn't make reference to a clear theoretical foundation except 'evolution', which has been generalised in an indeterminate way to all Big Historical eras. This reduces external validity. Grinin marks periods by the emergence of new kinds of 'evolutionary dynamics'. However, the more precise nature of these is not elucidated – what kinds of specific mechanisms lead to successful transitions are not identified. For example, Grinin postulates the existence of a 'biosocial' transitional phase between his biological and social phases, but argues simply that the transition occurs because evolutionary processes introduce social relations among organisms. This is not an explanation but a description. Suggesting that successful transitions are preceded by 'pre-adaptations' (that is, they are successful as a transitional phase, and endure for some time in that form, but then also work as a first step to a new major phase) only indicates that, post-facto, it so happened that one development proved to be the grounds for another one. This lack of defined mechanisms underlying transitions weakens the approach, although the division of transitions into a two-level hierarchy is meant to facilitate the eventual identification of such mechanisms. There is a real lack of specifics about the processes underlying periodization, so that the nominal idea of an 'evolutionary transition' is a weak form of natural kind.

5. Discussion

The different approaches certainly exhibit a variety of strengths, although none seems to be strong across the board. Perhaps not unrelatedly, they also identify widely disparate events in the various Big Historical eras and different reasons for the historical momentum toward increasing complexity. This leaves us in the unenviable position of not being able to point to a 'winner' in the theoretical sweepstakes nor to identify an accepted sequence or periodization for the discipline. However, there is some agreement among the approaches as to the importance of a few periods or events, which appear on the lists of at least three of the candidates (shown in bold in Table 2): the appearance of atomic particles, stars, planets, complex chemicals, the origin of life, complex cells, multi-cellular organisms, social groups, language or human culture, agriculture and modern civilization. So it appears there *is* a degree of consensus around a 'minimal list' – one that is actually close to the original list put forward for the discipline (seven of Christian's eight thresholds make this minimal list of eleven periods). While interesting, this doesn't constitute a scientifically grounded way to consolidate opinion around which events are intrinsic to Big History.

Few of the candidate approaches are parsimonious in the sense of relying on a single theory – although given the scope of Big History, this may not be too surprising. One strategy to cover this range of phenomena has been to rely on generic theories, such as cybernetics or systems theory, but these tend to lack the specificity to allow empirical testing – at least at current levels of development – and to leave Big History without clear reference to, or embeddedness in, related fields. Some approaches also appear not to be 'complete' in the sense of providing explicit theories about both trend dynamics and periodization (e.g., just noting that the trend is toward increasing complexity).

Other aspects of the approaches need discussion. First, several scholars have argued that the tripartite principles underlying the 'Darwinian algorithm' – of variation, selection and inheritance – operate in all Big History eras

Table 1: Characteristics of the Alternative Perspectives on Big History

Quality	Self-Organising Universe	Grand Unified Narrative	Cosmic Evolution	Perasmology	Extended Evolution	Grand Sequence	Mega Evolution
Trend dynamic	Non-equilibrium thermo-dynamics	'Emergence'	Thermo-dynamics	Non-equilibrium thermo-dynamics	Thermo-dynamics/ 'Extended' evolution	Increasing complexity	Increasing complexity
Unique trend metric	Energy gradients	????	Free energy flow density	Free energy flow density	Energy flow	????	????
Period-inducing mechanisms	Self-organisation (non-equilibrium thermodynamics of dissipative structures)	'Goldilocks conditions'	????	Three-part transition involving energy innovation, novel organisation, and emerging control mechanism	New kinds of information processing and energy extraction	Combo-genesis; 'PVSR dynamics' (Darwinian processes of variation, selection and inheritance)	'Pre-adaptations'
Natural kind unit	Regime	Threshold/ Regime	????	NESST	Evolutionary transition	Level/ Realm	Evolutionary transition
Empirical testability	Medium	Low	High	High	Low	Medium	Medium
Degree of parsimony	Low	Low	High	Low	Low	Low	High
External validity	Medium	Low	High	Medium	Medium	Low	Low
Strengths	Addresses a wide range of elements (energy, information); Links micro- and macro-scale processes	Defined Big History as a discipline	Fundamental theoretical foundation, empirical metric	Unique process model encompassing information, energy, and structure	Synthesizes a number of prior approaches	Makes testable claims	Hierarchy of transitions potentially illuminates transition mechanisms
Weaknesses	No model of transition process	'Thresholds' chosen for pedagogic, not scientific value; Reliance on narrative characteristic of humanities; 'Goldilocks conditions' are specific to each Threshold	Lack of intrinsic transition dynamic; Theoretical foundation not specific to Big History	Not theoretically parsimonious	Lack of Big History-specific modelling	Use of Darwinian algorithm to describe transitions; Combogenesis remains abstract concept; Lack of trend-producing mechanism; No process link between levels and realms	Use of evolution concept not fully Darwinian; Transition mechanisms not identified
Reference discipline	Physics, Systems science	History, Cosmology	Physics	Physics, Biology	Physics, Cybernetics	Biology	Biology
Primary proponents	Jantsch 1980	Christian 2004; Spier 2015	Chaisson 2001/2005	Aunger 2007a,b	LePoire 2016	Henriques/ Volk 2023	Grinin in press

Table 2: Periods identified by the candidate approaches*

Period	Self-Organising Universe	Grand Unified Narrative	Cosmic Evolution	Perasmology	Complex adaptive systems	Grand Sequence	Mega Evolution
Cosmological era							
Big Bang/ Quanta		X				X	
Photons	X						
Leptons	X						
Baryons	X						
Nucleons	X					X	
Atomic nuclei	X					X	
Atoms/ Gravitational elements/ Particulate/ Inflationary	**X**		**X**	**X**	**X**	**X**	**X**
Molecules/ Pre-stellar	X					X	X
Stars	**X**	**X**	**X**	**X**			**X**
Stellar clusters	X						
Galaxies	X		X	X			
Galaxy clusters	X						
Superclusters	X						
Geological era							
Planets	**X**	**X**	**X**		**X**		**X**
Chemical/ Geological		**X**	**X**				**X**
Crystals	X						
Chemical abiogenic/ Rock formations	X						X
Gaia system	X						
Biological era							
Prokaryotic cells/ Origin of life	**X**	**X**		**X**		**X**	**X**
Eukaryotic cells	**X**			**X**	**X**	**X**	
Heterotrophic ecosystems	X						
Multicellular organisms/ Cambrian explosion	**X**			**X**	**X**	**X**	
Social groups/ Mammals	**X**			**X**	**X**	**X**	**X**
Primates					X		
Human era							
Hominids/ Anthropogenesis					X		X
Humans					X		
Division of labour	X						
Band/ (Human) Social				X			X
Tribe				X		X	
Human language/ Speech/ Culture	**X**	**X**	**X**		**X**		
Fire					X		
Eco-adaptation					X		
Modern humans					X		
Agrovillages		**X**			**X**	**X**	
Cultural era							
Civilization	X				X		
Chiefdom				X			
Geopolitical states				X		X	
Commercial revolution					X		
Scientific/ Exploration					X		
Industrial				X	X		
Information revolution/ Multi-national				X			
Globalization/ Modern life		**X**		**X**	**X**		
Primary proponents	Jantsch 1980	Christian 2008	Chaisson 2005 (Epic)	Aunger 2007a,b	LePoire 2106	Henriques/ Volk 2023	Grinin in press

* The set of entries in this table do not bear close resemblance to those in (Aunger, 2007b) for the same authors because that earlier compilation concerned events, not transitions, about which these authors have become more explicit (e.g., (Christian, 2008)) since that earlier publication.

(Baker, 2017; Grinin et al., 2011; Grinin, 2019; Volk, 2020; Henriques & Volk, 2023). This argument is often based on work by others suggesting the algorithm operates among multiple potential universes (Smolin, 1997; Harrison, 1995; Vidal, 2014), in the realm of minerals (to define planetary accretion and composition), among genes or individuals (as parts of biological populations) (Darwin, 1859), and between cultural variants (Dawkins, 1976). This algorithm is thus seen by them as the driver of increasing complexity across all eras of Big History, not just during the life and culture eras. As Henriques and Volk note, this is an empirical claim that can be investigated (Henriques & Volk, 2023)?

Unfortunately, the authors advocating the broad applicability of Darwin's insight about natural selection provide few examples of how to apply the Darwinian Algorithm to the central topics of these different eras in Big History. There appears to be little academic conversation around the proposition that there is variation and adjustment in the composition of individual planets due to selection, or among the bodies circling a star; in particular, how information inheritance might figure in these domains has not been explored to my knowledge. The multiverse concept remains highly contentious among cosmologists (Saunders et al., 2010; Kragh, 2009; Gordon, 2011); there is even debate that the Darwinian algorithm provides a good explanation for the mechanics of cultural evolution (via the meme analogy to genes) (Aunger, 2002; Chvaja, 2020; Kronfeldner, 2014). So while the notion of 'evolution' is regularly applied to aspects of change in the full range of Big Historical systems, the specific Darwinian algorithm most likely does not apply to domains outside of biology. [vii] (This is not so say that there aren't evolutionary processes operating outside of biology; for example, a plausible argument has been made that the number, types and complexity of minerals have increased over time on earth, due to a number of specific processes (Hazen et al., 2008).)

Later approaches do not seem to be scientifically stronger, nor always rely on advances made by previous approaches (excepting LePoire), indicating a lack of progressivism in Big History. Jantsch got to diagrammatic-level specificity already by 1980, although he did not engage in quantitative modelling, nor the dating of events. To be fair, most contemporary Big Historical approaches remain conceptual in nature rather than being couched as formal models (although one school is centrally concerned with event dating (Panov, 2005; Modis, 2002; Korotayev & Eurasian, 2018). This limits the degree to which the claims of such approaches can be empirically tested. Tests are still possible, however. For example, since Extended Evolutionary transitions begin with an information storage or transmission innovation, while Perasmological transitions start with an energy capture innovation, this represents a testable contradiction between these approaches. Similar kinds of tests should be identified and investigated.

6. Conclusion

There has now been nearly fifty years of theorising about Big History. What renders all Big History approaches similar is the basic proposition that phenomena arising at different spatial and temporal scales since the origin of the universe – cosmic, geological, biological and cultural – can be linked causally into a unified story about the increasing complexity of outcomes from similar, but distinct, processes. This philosophical choice of cycles-within-trend as the overall pattern of history gives Big History a particular flavour and meaningfulness: it has a grand scope and potential for an inspirational narrative (leading to a favoured outcome), while also encompassing sufficient content to find patterns capable of being empirically tested. However, identifying sound rationales for periodization and long-term trend dynamics continue to be central theoretical problems for Big History.

In this paper, I have therefore compared approaches that seek to explain history from the Big Bang to contemporary human society using particular theoretical frameworks. The comparison is based on various grounds linked to the scientific soundness of these frameworks. While several approaches cope fairly well with an analysis of their scientific merit, the primary conclusion from this comparison is that Big History has a way to go, both in terms of identifying a theoretical approach with strong foundations, and in achieving a consensus around this theoretical core. In one sense little progress has been made because Jantsch presented an approach in 1980 that is as sophisticated as contemporary offerings.

Progress is rather around a developing sense of consensus, not an actual approach. A number of things seem to be agreed upon (Aunger, 2007a; LePoire, 2016; LePoire, in press; Henriques & Volk, 2023; Grinin, in press):

- The Big Historical trend is about increasing maximal complexity over time
- This trend is broken up into temporal sections at multiple levels of importance (called here 'eras', and within eras, 'periods')
- A single theory encompassing the physical, chemical/geological, biological and cultural eras is possible
- Eras and periods are defined by unique dynamics
- Significant changes in some value (e.g., energy flow density, or reaching system capacity) create the conditions that initiate transitions to new periods and eras
- Transitions into new periods are themselves complex, involving changes in energy flow, information and structure.

But currently, there is little in the way of consensus about the best theory to explain these phenomena, nor around a set of canonical periods that define the Big History narrative – the central problems identified in our introduction. It is difficult to know how to get to a consensus on these issues as there is a tendency for each scholar to develop and prefer an independently created theoretical approach.

One way forward might be to determine the best strategy for theory development. The approaches covered here have each made one of the following choices to cover the broad range of phenomena that define Big History: use a cross-disciplinary theory (systems theory, self-organisation), generalize a discipline-specific theory ('evolution', the Darwinian algorithm, major evolutionary transition theory), or invent a novel theory (e.g., combogenesis). Each of these strategies has advantages, but all require further development to be brought to the point of broad testability. Some tests are currently possible, however. For example, some of the claims about the internal sequencing of transitional phases are different between approaches, and so can be investigated, to come down in favour of one or another of the theoretical approaches covered here, producing an evidentiary basis for preference that could lead to consensus.

As for utility claims, thus far the argument has largely been that simply placing events into a different, larger context (e.g., human history within the history of life on Earth), provides sufficient reason to engage in Big Historical narrative-building. However, for those not convinced by this argument, more ambitious rationales may be required. For such critics, it may also be necessary to produce a body of empirical work – for example, case studies or the 'little Big Histories' of Quaedackers (Quaedackers, 2019) – which demonstrates that novel findings about important historical processes and events can be discovered through use of Big Historical theory or perspectives. While theoretical issues will take time to settle down, empirical endeavours can proceed immediately and will likely contribute significantly to the reputation of Big History as a discipline.

Acknowledgements

Thanks to David LePoire for granting me access to several publications in press, including one of his own, and to Deborah Colson for reading an earlier version.

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Endnotes

[i] There is also the problem that physical/cosmological periods become longer with the passage of time, while biological/social/technological ones become shorter (Korotayev & Eurasian, 2018; LePoire, in press). This too requires explanation.

[ii] LePoire has recently suggested a similar, but larger set of criteria on which to evaluate periodization frameworks, some of which are specific to Big History, unlike here (LePoire, in press).

[iii] A major sub-literature concerns efforts to identify dates for periods by fitting exponential curves to historical data (Panov, 2005; Modis, 2002; Korotayev & Eurasian, 2018). This requires setting a beginning date and acceleration or deceleration rate; the combination defines a curve on a graph of time since the present day against the time between significant events. This curve is then used to identify event times in Big History, for which evidence of emergent novelties occurring at those points in time are then sought (Panov, 2005; Snooks, 2005; Modis, 2002). Sometimes, the timing of the nominated events is chosen post-hoc, to better fit the estimated line. (Using time on both sides of the equation (Panov, 2005; Kurzweil, 2005) is also conceptually problematic.) Alternatively, some scholars start by arguing that 'learning' is the mechanism that causes geometric acceleration in the cycles with each repeat, using Christian's Grand Unified Narrative threshold set of events as a starting point against which to fit the acceleration factor. On such a graph, one can then place points that represent significant events in Big History. These points can be read as defining how fast major changes were occurring at various times in the past (e.g., around 2000 years ago, macroevolutionary shifts tended to happen at the rate of one per millennium) (Korotayev & Eurasian, 2018).

However, describing Big History via an exponential function (Panov, 2005; Modis, 2002; Kurzweil, 2005) only produces a line on which an arbitrary number of 'events' can be placed, as a line can be divided up in infinite ways. It therefore is not strictly determinative of what parts of that line count as a period – that is, it doesn't tell you which points on the curve count as inflection points in the underlying dynamic. All that has really been accomplished is a recognition that it is possible to describe some sets of events or periods with a simple two-variable equation involving time and a rate of acceleration. This work thus describes, but does not explain, historical trends, or events within them, especially when no rationale is given for the increasing momentum such lines describe. The generality of the approach (it also works to describe the increase in human population over time (Korotayev & Eurasian, 2018)) means it could simply be the consequence of some feature shared by many kinds of phenomena, and hence is not unique to Big History. From a theoretical point of view, this is unsatisfying, despite the mathematical neatness of the description.

[iv] I should note that I exclude from consideration a number of nineteenth-century predecessors such as (Chambers, 1844; von Humboldt, 1845; Fiske, 1874), all of whom used pre-Darwinian, and hence vague, notions of 'evolution' to cover material from the cosmological to the cultural in a single narrative. While laudable in the sense of adopting the same kind of perspective and ambition as contemporary Big Historians, and often covering the same eras, much less was known scientifically about all of these eras than in the 21st century, so there was neither the same kind of theorizing about trend nor periodization as became possible more recently.

[v] Henriques and Volk argue that non-human animal cognitive decision-making, which represents a new evolutionary dynamic based on within-individual Darwinian psychological mechanisms, is unique to their approach. This is true, within Big Historical accounts; however, this mechanism can be found in several prior works outside of Big History (Aunger, 2002; Fernando et al., 2012; Edelman, 1993).)

[vi] The complex adaptive systems modelling preferred by the Extended Evolutionary approach can also lead to self-organising or emergent outcomes in some cases, but is not the primary focus of such modelling.

[vii] Note that this is an argument against the operation of a *micro*-evolutionary mechanism across all Big History eras. It does not apply to macro-evolutionary mechanisms, such as major evolutionary transitions. Natural selection is a mechanism describing change between generations in biological populations, and so is couched at the wrong scale to explain the macro-scale events characteristic of Big History.