Introduction to this Special Issue: “Continuously evolving to bridge significant gaps in our understanding of complexity”

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Although complexity plays a significant role in big history, substantial gaps persist in our comprehension. While the papers in this issue do not provide definitive answers to these gaps, they contribute to the ongoing discussion on how to address these issues and propose potential pathways for resolution. These gaps encompass measurement, focus, organization, relevance, consistency, and interpretation. While there may not be unanimous agreement on the specific direction to take, the academic discussions evident in these papers aim to elucidate the issues and foster understanding within the expansive and diverse scientific community.

The theme of this special edition is "*Evolving Continuously to Bridge Substantial Gaps in Our Understanding of Complexity*." Comprising 14 articles, including this Introduction, the issue is organized with a focus on complexity growth, evolution, and various aspects. The articles on growth explore methodologies for measuring, assessing, and examining the symmetry of singularity trends in complexity within the framework of Big History. Those addressing complexity and evolution delve into perspectives such as chaotic cascades, general evolution, selection, and chemical evolution. The aspects section encompasses discussions on integration with traditional academic disciplines, handling the multidirectional aspects of complexity, practical applications of complexity science, proposing an approach to interpreting the Big History journey, and comparing the process to cybernetic models.

The significance of the concept of complexity, along with its various facets, is not merely substantial; it forms the very structure of understanding. When contemplating the broadest concepts that can encompass the entirety of Big History or the field of evolutionary studies, only a handful stand out. These include notions tied to evolutionary dynamics, such as development, change, and progress, yet these concepts often spark debates. Central among them are energy and entropy, and to a lesser extent, self-organization—encompassing crucial aspects of energetic and structural ordering. Information is also a contender, though the period at which it becomes an independent aspect of evolution remains a subject of debate. However, we contend that one can fundamentally discuss information from the inception of Big History.

Arguably, few would dispute that complexity stands as one of the key concepts in Big History. Yet, given the substantial gaps in our understanding of the complexity concept, any novel ideas or hypotheses are warmly welcomed.

The complexity growth papers delve into fundamental questions of measurement, assessment, and symmetry of patterns. **Nick Nielsen** (“A Complexity Ladder for Big History”) suggests that big history could draw inspiration from astronomy, where a unifying ladder of distance measurement was constructed to handle diverse spatial and temporal scales. This ladder extended from the size and distances of the Earth-moon-sun system to other stars and galaxies, allowing telescopes across the electromagnetic spectrum to explore phenomena across different scales and times. **Robert Aunger** (“On Trends and Periods“) specifically examines diverse approaches to framing periodization within big history, having previously introduced the NESST (non-equilibrium thermodynamic steady-states) that has been referenced in big history papers.

Andrey Korotayev’s “Patterns of complexity growth in the Big History. A preliminary quantitative analysis” introduces a framework for examining the two singularity trends, one at the inception of the universe and the other during the current global transition on Earth. The singularity trend of cooling following the big bang has given rise to more intricate systems with greater potential for complexity. Steven Weinberg's 1979/1993 book, "The First Three Minutes," highlights that much of the complexity potential, including forces, particles, and interactions, was realized within the initial minutes of the universe. Interestingly, the somewhat evenly spaced physics energy scales (e.g., nuclear, atomic, molecular, solids) contribute to this singularity cooling trend, although the fundamental reason remains unknown.

Contrastingly, bio-social evolution on Earth originated from the bottom up as life emerged through a yet-to-be-understood process. Advances in complexity appear to have accelerated complexity rates, aligning with a process identified by Manfred Eigen in evolutionary systems, leading to trends suggestive of unlimited change within a finite time (singularity trends). While no actual singularity emerged due to system constraints, the population growth trend followed a similar pattern from ancient times until the early 1970s when limits became evident.

As criteria for evaluating patterns in big history are still under development, this theme of authors proposing "natural" divisions in big history persists in the works of Hoggard, Glötzl, and Grinchenko. **Nick Hoggard** ("From Big Bang to Chaotic Complexity: A Theory of Big Evolution") proposes a sequence based on the Feigenbaum cascade to chaos, using a scaling factor of about 4.67. **Erhard Glötzl** ("The General Evolutionary Theory as Unification of Biological and Cultural Evolution: A Basis for a Natural Periodization") considers natural evolutionary transitions in information processing in an extended and integrated Darwinian evolution of genetic and cultural evolution. **Sergey Grinchenko** ("Big History in the Digital Perspective") employs critical levels of development phases derived from the work of Zhirmunsky to suggest a sequence centered around the identified critical number of e^e (about 15). The diversity of sequences with different factors suggests the need for a more precisely defined and assessed set of criteria. The prior special issue on periodization did propose such criteria and developed a framework aligning with traditional fields based on previous findings.

Borje Ekstig, known for developing relationships between evolution and development over evolutionary time, contributes to evolutionary thinking by offering a fresh perspective on natural selection ("Selection and Increasing Complexity in Evolution"). He emphasizes that natural selection, while contributing to changing system complexity, is not merely a reactionary phenomenon. Systems naturally selected in an environment often alter the environment through increased growth or efficiency, sometimes at the cost of resilience and robustness. This co-evolutionary dynamic between organisms and systems played a crucial role in the physical and social evolution of modern humans during the transition from predominantly genetic evolution to primarily cultural evolution.

Leonid Grinin's "Chemical Evolution in Big History" adopts a broader outlook on the evolution of materials, spanning from the formation of matter shortly after the big bang (a process still not fully understood) to the contemporary utilization of materials in technology. The journey encompasses the creation and dissemination of elements from stellar interiors, the formation of planets, and the development of special molecules like water, oxygen, carbon dioxide, and silicates. The emergence of life from the chemical materials on early Earth remains a fervently pursued topic, with multiple avenues being explored to triangulate possible scenarios. The ongoing revelation of phenomena arising naturally or through engineering with relatively simple chemical elements continues to be surprising. This perspective on materials and how systems evolved to leverage these phenomena complements the traditional focus on complex systems. A similar viewpoint was previously emphasized in Jantsch's and Panov's timeline of evolving systems and environments (and tools), underscoring the importance of maintaining this perspective's freshness.

Within the papers addressing aspects, various issues are explored, including alignment with academia, practical application, pondering the big journey. Although complexity holds significant importance not only in big history but also in diverse fields such as economics, sociology, cognitive science, computer science, and physics (see LePoire et al. 2023)[1], its definition remains elusive, and ongoing

[1] LePoire D.J, Grinin L.E., Korotayev A.V. 2023 Evolution: Complexity in Nature, Society, and Cognition 2023 5–22 DOI: 10.30884/978-5-7057-6261-3_01

discussions surround its measurement. The complexity in big history presents an additional challenge due to the broad spectrum of phenomena it encompasses, ranging from the big bang to cosmic development, and the evolution of life, humans, and civilizations.)

Lowell Gustafson ("Emergent Complexity: A Rationale for the University") argues that while academia supports many aspects of big history, its integration still faces challenges related to disciplinary boundaries. He notes that big history often concentrates on the narrow path of increasing complexity, overlooking the fact that most systems either become extinct, get stuck in complexity, or revert to simpler states.

Ken Baskin's examination of systems analysis in big history highlights the potential application of various systems concepts, including punctuated equilibrium, scaling behavior, energy dissipation, information sensing, storage, processing, and learning ("The Practical Application of Complexity Science to Enhance Big History"). This becomes crucial as big history not only delves into the narrative from the big bang to the present but also broadens its scope to encompass more dynamics, addressing the 'how' and 'why' (as well as the 'how not' and 'why not') of systems evolution. This expanded perspective allows for the inclusion of systems that did not persevere along seemingly promising paths, the consideration of simplification as a potentially advantageous path for some systems, and an exploration of how internal growth dynamics, such as panarchy systems, might pose challenges as they expand, prompting a continual quest for more complex trajectories.

Marc Widdowson ("Last stop on the cosmic journey: An estimated time of arrival") adopts a distinct perspective by not focusing on the singularity inflection point, but rather on the time when society could potentially reach its peak measured by the optimal utilization of energy. He analyzes trends in energy consumption and assesses them on the Kardashev scale to investigate the potential timing of this technological utopia. The emphasis for the reader is not in the precise prediction date, but rather in appreciating the thought process concerning how technology and energy utilization might scale in the future.

This issue of JBH also features two non-papers, offering unique perspectives. **Gustavo Lau** "Perspectives: Sharing Inside Brains" provides insight into using analogies to examine the organization of books and collections. Not only does he delve into these topics, but he has also played a pivotal role in constructing a system with remote connections to students in Venezuela from his current residence in England. Lau's infectious enthusiasm for teaching and testing new ideas is evident as he explores abstract concepts, a big history book collection, and organizational thoughts inspired by Bill Gates.

Another contribution focuses on the development of a reference-citation database for big history by **David LePoire** "An Approach to Categorize Big History Papers". This database encompasses JBH papers, Russian Yearbooks papers, and listings of big history books, creating a searchable resource for efficiently using and managing references in papers. LePoire has implemented a categorization scheme based on ideas for periodization, incorporating three dimensions: the phase of big history evolution (cosmic, life, humans, civilization), the aspect of complexity (energy, information, organization, environment), and the type of research (framework, education, discipline, integration). This database is accessible online and shared for everyone to use.

Heartfelt thanks are extended to all the authors for their hard work and imaginative contributions to shaping these papers. The majority of these papers underwent peer review by the same group within the complexity project, which anticipates at least another JBH issue. One way to express gratitude is by engaging with the content—reading, contemplating, and initiating conversations with the authors. Whether you have questions, disagreements, or ideas for extending their work, reaching out to them or sending letters to the JBH editor for publication in future issues is encouraged. This collaborative approach allows us to continue learning from each other, fostering meaningful dialogue despite our diverse backgrounds and experiences.

We hope that this special issue will be useful both for those who study Big History and for specialists working in focused directions, as well as for those who are interested in evolutionary issues of Cosmology, Biology, Psychology and other areas of study. More than that, this edition will challenge and excite your vision of your own life and the new discoveries going on around us.