FACTORS FOR IDENTIFYING NON-ANTHROPIC CONSCIOUS SYSTEMS

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ABSTRACT: One of the problems of identifying consciousness is defining it in ways that allow for universal application and exploration. Popular and anthropocentric definitions are problematic due to their inherent bias toward exclusively biological events in a field of study that does not require and is even hindered by this limitation. A preliminary definition is needed that would encompass known biological consciousness as well as theoretical macro, micro, and intrinsic levels of consciousness. This paper proposes that the following are a preliminary set of factors for openly exploring what can be considered conscious with no biological or cultural biases.

1. **Communication**: Consciousness requires discrete parts of the system to be able to influence one another in a holistic manner. Whether this is by synaptic firing or gravitic relationships is irrelevant.
2. **Adaptation**: Consciousness requires adaptation to its environment. Note the avoidance of the popular term "awareness," which is an untestable factor on many levels. Static systems cannot be conscious. Dynamic systems can be, but are not necessarily conscious.
3. **Complexity**: In order to be differentiated from purely physical or chemical dynamic systems, conscious systems must display a sufficient complexity in energy rate density. This paper proposes a ϕ_m (erg/second/gram) of a minimum of 10^3 for any given system to be considered complex enough to display consciousness. This is equivalent to the simplest lifeforms considered conscious.

The first two requirements are easily understood. The requirement of complexity is the least conventional and requires explication. Physical complexity is often used as a basic threshold for organization, but this seems to be due to convenience more than logical applicability, especially when informational systems are weighed on their quantitative value. It does not follow that a greater number of components translates to a higher threshold of complexity, any more than saying a bucket of sand is more physically complex than an iPad because it has more particulates.

As Eric Chaisson posits, energy rate density is a more universal and reliable means of organizing complexity. Energy rate density (ERD) measures the energy flow in ergs per gram per second within a given system. This qualitative assessment of energy efficiency is more insightful than listing non-adaptive arrangements such as physical interactions or even systems theory. The dramatic spike in ERD for all known conscious systems makes this an ideal metric for exploring radically different systems about which little else is known.

KEYWORDS: Communication; Adaptation; Complexity; Energy Rate Density

INTRODUCTION

The concept of identifying consciousness is a complicated issue to address in an interdisciplinary manner, in large part because various disciplines have entirely different definitions and terms. Philosophy of mind, neurobiology, psychology, and quantum physics all use the same term in distinct, even exclusionary ways, which minimizes the potential for meaningful interdisciplinary work. There are significant ramifications to this issue, as research into consciousness influences what systems are considered inert, alive, and/or sentient. Both of the popular solutions to these conflicting definitions present their own problems.

The first and most common solution is to proceed as if there were no other concepts of consciousness beyond one's own discipline. Quantum physicists explore implications of wave function collapse without mentioning the biological requisites of the observer, while neuroscientists examine how the human mind processes its environment without extrapolating this analysis to nonhuman entities. These oversights represent the abrogation of the scientific duty to coordinate knowledge across disciplines. Specialization in the pursuit of highly technical research is necessary in science, but those specialized findings must be able to be reintroduced in a comprehensible format to the general academic community. Exclusive terminology prevents this collaboration and thereby makes the research of interdisciplinary or systems-based hypotheses more difficult.

The other solution involves generalizing terminology until it is ambiguous enough that it can apply to multiple disciplines. The problems with this approach are more nuanced: the underlying conflicts are ignored rather than resolved, and the ambiguity allows anthropocentric biases to subconsciously influence research. The latter issue is more insidious, as it may mask the need for new paradigms of inquiry. Examples of anthropocentric biases in consciousness theory include Turing's Imitation Game and reliance on biological processes to determine conscious behavior. In both cases it is often erroneously assumed that anthropic manifestations of conscious behavior are defining rather than expressive.

This paper will discuss a potential set of defining factors of conscious systems that are both clearly delineated and multi-disciplinary. This approach is intended to minimize anthropocentricity and supplement rather than replace existing conceptions of consciousness. It is important to note that the intent of this paper is not to announce new discoveries in consciousness, but to propose a new paradigm with which to search for said discoveries. The proposed factors will be defined below, with each section structured to explore the necessity, terminology, and benefits of the new factor. A final summary will examine the broader implications of this approach to systems that display conscious characteristics.

FACTORS: OVERVIEW

For the purposes of this paradigm non-anthropic consciousness (also referred to as conscious systems) is defined as a complex adaptive system with a minimum energy rate density. Further definitions regarding internal processes, quantum implications, intelligence, and sentience are retained by specialists in those fields. While all known conscious systems are biological organisms, this paradigm does not require that prerequisite. This proposal is a minimal shared baseline, and its divergence from generally accepted models of consciousness is intentional. The minimum factors proposed to identify conscious systems include:

1. **Communication**: Conscious systems require discrete parts of the system to be able to influence one another in a holistic manner. Whether this is by synaptic firing or gravity is irrelevant.
2. **Adaptation**: Consciousness requires adaptation to the environment and selective behavior. Static systems cannot be conscious. Dynamic systems can be, but are not necessarily conscious.
3. **Complexity**: In order to be differentiated from purely physical or chemical dynamic systems, conscious systems must display a sufficient complexity in energy rate density. This paper proposes a Φ_m (erg/second/gram) of a minimum of 10^3 for any given system to be considered complex enough to display consciousness. This is equivalent to the simplest lifeforms considered conscious.[1]

These factors are co-requisites for identifying conscious systems, and are inapplicable independently. Conscious systems share many of the qualities of complex adaptive

1 E. J. Chaisson, "Energy Rate Density as a Complexity Metric and Evolutionary Driver," *Complexity* 16, no. 3 (January 1, 2011): 27–40, doi:10.1002/cplx.20323.

systems, and may even be considered a subcategory. As with complex adaptive systems, conscious systems must be analyzed in a holistic manner, as the complexity of the dynamic system equals more than the sum of its parts.[2] For example, a cat is made up of carbon, calcium, and neurons, to name a few materials, yet one cannot extrapolate the behavior of the whole organism by examining the proteins, bones, or brain in isolation. The conscious system that is the cat encompasses the relationships of its component parts as much as their physical properties.

Conscious systems generally share the following traits with complex adaptive systems:[3]

- The number of elements is sufficiently large that conventional descriptions (e.g. a system of differential equations) are not only impractical, but cease to assist in understanding the system. Moreover, the elements interact dynamically, and the interactions can be physical or communicative.
- Such interactions are rich, i.e. any element or sub-system in the system is affected by and affects several other elements or sub-systems.
- The interactions are non-linear: small changes in inputs, physical interactions or stimuli can cause large effects or very significant changes in outputs.
- Interactions are primarily but not exclusively with immediate neighbors and the nature of the influence is modulated.
- Any interaction can feed back onto itself directly or after a number of intervening stages. Such feedback-loops can vary in quality.
- Such systems may be open and it may be difficult or impossible to define system boundaries.
- Complex/conscious systems operate under far from equilibrium conditions. There must be a constant flow of energy to maintain the organization of the system.
- Complex/conscious systems are dynamic and evolve. Their past is co-responsible for their present behavior.
- Elements in the system may be ignorant of the behavior of the system as a whole, responding only to the information or physical stimuli available to them locally while still remaining within the greater system.

2 "Study on Complex Adaptive System and Agent-Based Modeling&Simulation--Acta Simulata Systematica Sinica, 2004年01期"

3 P. Cilliers and David Spurrett, "Complexity and Post-Modernism: Understanding Complex Systems," *South African Journal of Philosophy* 18, no. 2 (May 1, 1999): 258–74, doi:10.1080/02580136.1999.10878187.

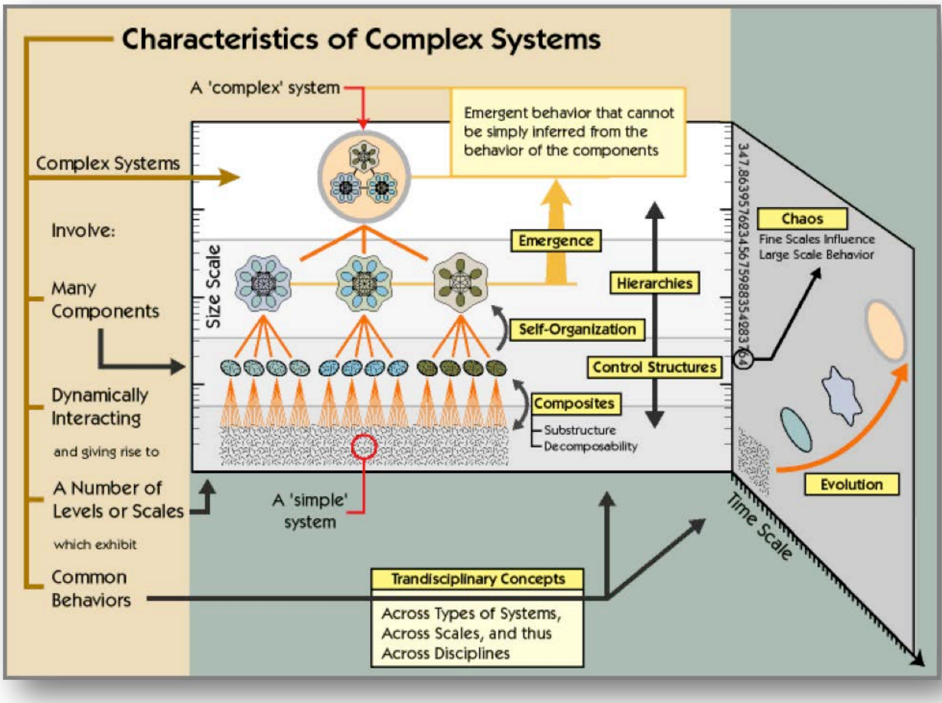


Diagram courtesy of *Evolution and Control of Complexity*, Argonne National Laboratory. www1.aps.anl.gov

When the following sections refer to the factors that help identify conscious systems, it is with the understanding that they are the initial points of reference for interdisciplinary communication and that the above traits are inherent in a systems-level approach to consciousness. It is not necessary nor productive for all research to be at a systems-level, and furthermore this paradigm is applicable to interdisciplinary studies that never approach the traits above. What cannot be ignored is the interconnected, holistic nature of the factors, which is defined in the traits above and in the individual descriptions of the factors below.

FACTORS: COMMUNICATION

The most basic element of a conscious system, as in any complex system, is the ability for one part to influence another. Without a means of transferring information, i.e. communication, there are only localized events without a system, and necessarily without consciousness. This factor is applicable to most disciplines, a small selection of which are listed here:

1. Physics: At their most fundamental, systems are bounded together and transfer either matter or energy between their parts.[4]
2. Neuroscience: Neuropsychology, cognitive psychology, and cognitive science agree that the intake of information is key to their discipline.[5]
3. Philosophy: The willful transmission of information is at the root of most philosophy of mind theories, and even the strictest Cartesians acknowledge the existence of internal communication.

While the most well-known vector for transmitting information for humans is the nervous system, theoretical communication vectors are wide-spread. Environmental vectors have been widely studied, exploring the means by which ecosystems communicate through their disparate parts, and this has led to numerous theories about the viability of ecosystems as conscious systems in their own right.[6]

Other potentials vectors for communication include gravitational fields, whose distortion of space-time allows interstellar bodies to influence and transmit information across vast distances of seemingly empty space.[7] Astronomical information is regularly transmitted to other bodies both massive and small, and this communicative potential cannot be ignored. The counterintuitive nature of gravity as a communication vector does not diminish its viability, and is an example of anthropocentric bias in conceptualizing the scale of complex systems.

4 Max Born, *Natural Philosophy Of Cause And Chance* (At The Clarendon Press, 1949), http://archive.org/details/naturalphilosoph032159mbp.

5 Posner, M. I.; Digirolamo, G. J. "Cognitive neuroscience: Origins and promise".Psychological Bulletin. 126 (6): 873–889. (2000). doi:10.1037/0033-2909.126.6.873. PMID 11107880

6 Timothy M. Lenton and Marcel van Oijen, "Gaia as a Complex Adaptive System," *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 357, no. 1421 (May 29, 2002): 683–95, doi:10.1098/rstb.2001.1014.

7 Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler, *Gravitation* (Macmillan, 1973).

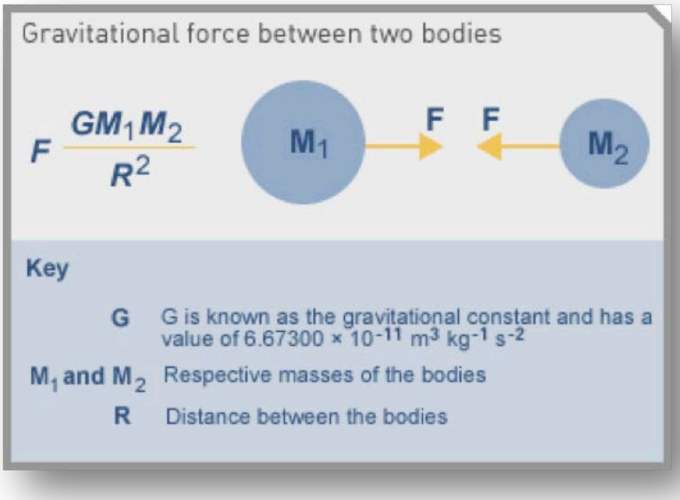


Image courtesy of http://www.makingthemodernworld.org.uk/learning_modules/maths/06.TU.02/?section=5

It is important to note that "communication" need not imply meaning or interpretation under this paradigm. While semiotics, and especially biosemiotics, pose compelling questions about the minimal requirements for information processing, they are beyond the scope of this proposal's focus on information transmission. While semiotics can only occur within conscious systems, it is not necessary for conscious systems to be semiotic.[8]

FACTORS: ADAPTATION

Most models defining consciousness in life forms agree that communication is an essential factor, and usually pair it with a requirement for an awareness of the environment.[9] This is a problematic requirement, however, as awareness is itself immeasurable and can only be deduced by observing behavior the researcher assumes to be influenced by an awareness of the environment. This is further complicated when interdisciplinary approaches cannot agree on whether conscious behavior is real, simulated, or if there is no distinction.

An example of this is Turing's Imitation Game, in which a human having a typed conversation with an unknown agent must decide whether that agent is a human (a

8 Jesper Hoffmeyer, *Biosemiotics* (University of Chicago Press, 2008).

9 David Snowden, "Complex Acts of Knowing: Paradox and Descriptive Self-awareness," *Journal of Knowledge Management* 6, no. 2 (May 1, 2002): 100–111, doi:10.1108/13673270210424639.

conscious system) or a computer imitating a human. At the point that the computer is consistently able to convince humans it is a conscious system, neuroscientists, philosophers, psychologists, and computer scientists argue one of three perspectives apply:[10]

1. The computer has become sophisticated enough to be considered conscious.
2. The computer is unconscious but is able to imitate conscious behavior.
3. If one cannot tell the difference between 1) & 2), the "reality" of consciousness is irrelevant.

These are actively debated and contested perspectives, and often deal with lines of inquiry specific to a given discipline. It is not necessary to declare whether adaptive behavior is due to "true" awareness or is simulation of such. The minimal scientific threshold is to establish testable evidence, not philosophical truths. Therefore this paradigm removes the factor of "awareness" and replaces it with the behavior that was actually being studied anyway, adaptation.

This is more than a semantic point. Attempting to define conscious systems by assuming they should be aware of their environment in the same way as known organisms necessarily limits our search to systems that are identical to known organisms. This is another cultural bias that must be overcome in order to investigate potentially counterintuitive conscious systems. To that point, the Imitation Game not only does not establish whether a system is conscious, its line of reasoning is fatally anthropocentric. Assuming human behavior equates to intelligent behavior excludes both unintelligent human behavior and intelligent nonhuman behavior. In the same way, assuming known conscious organisms equate to all conscious systems is a fallacy that can mask unexpected manifestations of adaptation.[11]

10 A.M. Turing, "Computing Machinery and Intelligence," *Mind*, no. 59 (1950): 433–60.
11 John R. Searle, "Minds, Brains, and Programs," *Behavioral and Brain Sciences* 3, no. 3 (September 1980): 417–424, doi:10.1017/S0140525X00005756.

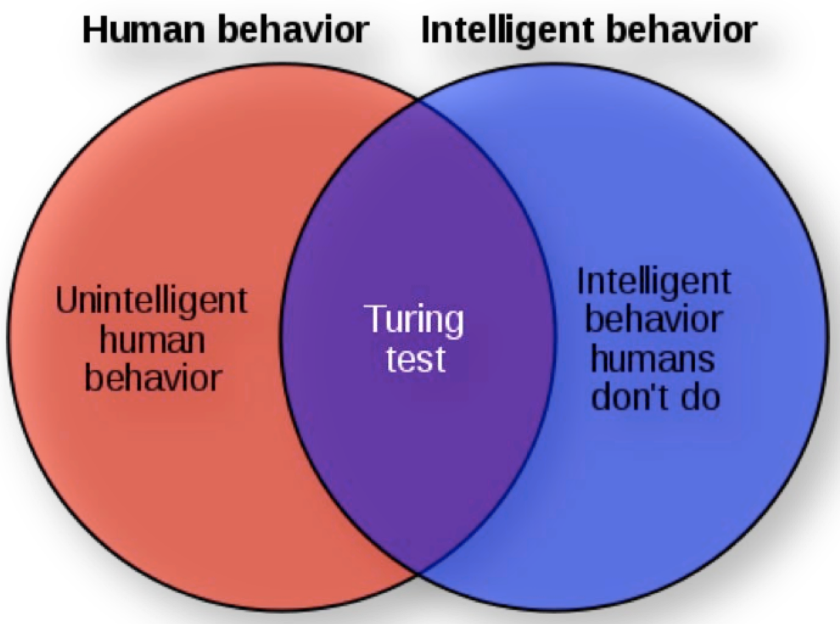


Image listed in public domain

Therefore the goal of this factor is to examine adaptive behaviors without preconceptions about biological evolution being the only correlate. Systems are adaptive if the individual and collective behavior mutate and self-organize corresponding to change-initiating micro-events or collections of events. A distinctive feature of conscious (and other complex adaptive) systems is the focus on top-level properties and features like self-similarity, complexity, emergence and self-organization. A conscious system is a complex, self-similar collectivity of interacting, adaptive agents, and are characterized by a high degree of adaptive capacity, giving them resilience in the face of perturbation.[12]

Adaptation is measured by complex reactions to environmental conditions, not necessarily with the survival of the potentially conscious system as a goal. Many known conscious organisms engage in destructive, illogical, or selected-against behavior, and it must be considered that new instances of conscious systems will reflect similarly obscure behavior.

Given these conditions it initially seems difficult to determine adaptive behavior, but an analysis of existing complex adaptive systems theory and chaos theory provides

12 Amit Gupta and S. Anish, "Tejas Article : Insights from Complexity Theory: Understanding Organizations Better," 2014, http://tejas.iimb.ac.in/articles/12.php.

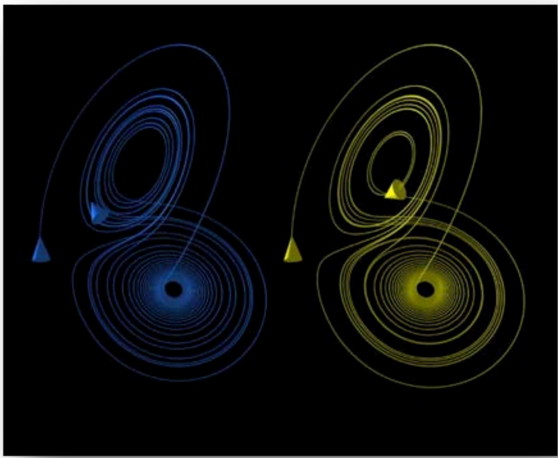
a blueprint for this paradigm. Though experts in these fields will be better able to provide concrete formulas for these adaptive behaviors, below are several examples of what to look for:

- Differing levels of reaction to stimuli indicate a conscious adaptation. This can take the form of a snail crawling over a pebble but retracting into its shell when poked, or increasingly volatile weather from an artificially warmed climate.[13]
- Non-linear, rich interactions result in highly complex behaviors that radically diverge from similar initial conditions. These behaviors also tend toward feedback-loops, which are a mechanism by which conscious systems can actively adapt.[14]
- The adaptive functions of consciousness can only exist in systems that are sufficiently complex to allow for unpredictable behaviors in response to the environment (sometimes explored as the root of "free will"). These conditions have similarities to chaos theory's bifurcation of complexity and strange attractors.[15]
- Currently existing biologically adaptive behaviors, which have been discussed extensively in many other sources and are well-know enough not to need expansion here.

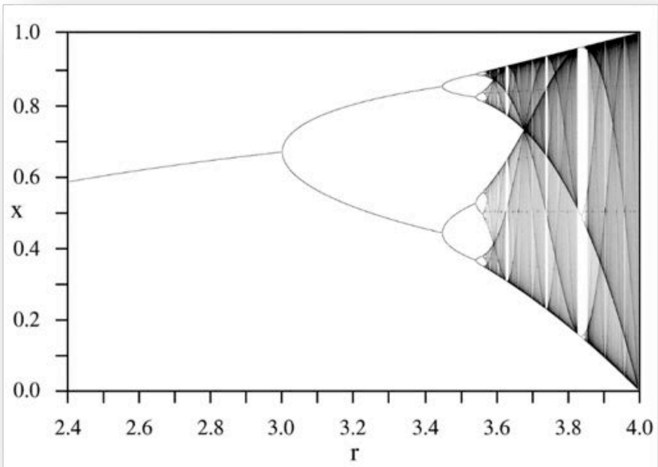
13 E. C, "A Behaviorist's Definition of Consciousness," *Psychological Review* 34, no. 6 (1927): 433–39, doi:10.1037/h0072254.

14 P. Cilliers and David Spurrett, "Complexity and Post-Modernism: Understanding Complex Systems," *South African Journal of Philosophy* 18, no. 2 (May 1, 1999): 258–74, doi:10.1080/02580136.1999.10878187.

15 Larry R. Vandervert, "Chaos Theory and the Evolution of Consciousness and Mind: A Thermodynamic-Holographic Resolution to the Mind-Body Problem," *New Ideas in Psychology* 13, no. 2 (July 1, 1995): 107–27, doi:10.1016/0732-118X(94)00047-7.



The Lorenz attractor displays chaotic behavior. These two plots demonstrate sensitive dependence on initial conditions within the region of phase space occupied by the attractor. Image is public domain



Bifurcation diagram of the logistic map $x \rightarrow r\,x\,(1 - x)$. Each vertical slice shows the attractor for a specific value of r. The diagram displays period-doubling as r increases, eventually producing chaos. Image is public domain

FACTORS: COMPLEXITY

Complexity is a frequently mentioned condition for the other factors listed above, being an integral component of physics, biology, systems theory, chaos theory, and complex adaptive system theories. This paradigm is intended for interdisciplinary use, however, and adopting highly discipline-specific interpretations of complexity creates the same problem this proposal is seeking to remedy. Therefore the measure of complexity needed to be an almost universally applicable formula that could reliably gauge the complexity of physical, biological, astronomical, chemical, systems-level, and cultural phenomena. The best method for doing so in an accessible, interdisciplinary manner is through measuring **energy rate density**.

Energy rate density is the **amount of energy per unit time per unit mass** (erg/s/g, or joule/s/kg). Regardless of the units used, energy rate density describes the flow of energy through any system of given mass.[16] This proposal suggests an expected ERD of 10^3, the lowest ERD of organisms known to be conscious. This should be considered a flexible boundary, given the variables and unknown issues in non-anthropic conscious systems.

Energy rate density is a general term that is equivalent to more specialized terms used by many different disciplinary scientists. For example, in astronomy it is called the luminosity-to-mass ratio (the inverse of the mass-luminosity ratio), in physics the power density, in geology the specific radiant flux (where "specific" denotes per unit mass), in biology the specific metabolic rate, and in engineering the power-to-weight ratio. Social scientists have recently begun exploring how ERD can be applied to cultural and systems phenomena.[17] ERD is a popular and useful tool among interdisciplinary scholars due to these universal applications.

Another benefit to ERD is the sharply visible distinction between the complexity of physical and chemical processes and complex systems, especially all known conscious systems.[18] The simplest organisms on Earth possess hundreds of times the complexity of the most complex discrete astronomical events. This feature makes ERD an ideal factor for identifying the complexity requisite in conscious systems.

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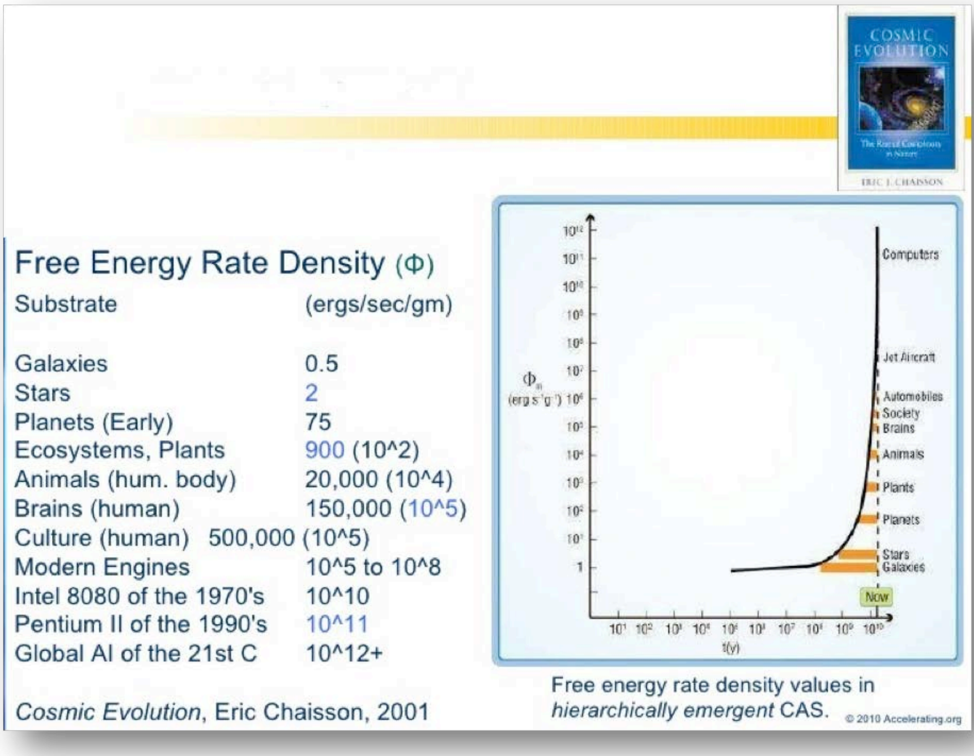
16 E. J. Chaisson, "Energy Rate Density as a Complexity Metric and Evolutionary Driver," *Complexity* 16, no. 3 (January 1, 2011): 27–40, doi:10.1002/cplx.20323.

17 Spier, F., Wiley-Blackwell, Big History and the Future of Humanity, New York, 2010.

18 Eric Chaisson, "The Life ERA: Cosmic Selection and Conscious Evolution," *Faculty Publications*, January 1, 1987, http://scholarship.haverford.edu/astronomy_facpubs/70.



Energy rate density is a more universal and reliable means of organizing complexity, especially for use as a general baseline.[19] Energy rate density measures the energy flow in ergs per gram per second within a given system. The dramatic spike in ERD for all known conscious systems also makes this an ideal metric for exploring radically different conscious systems about which little else is known.

The energy rate density of conscious systems that is currently limited to biological systems may be present at different scales of the measurable universe. While searching through combinations/scales for a conscious-level of ERD may be dismissed as "begging the question," this is no more fallacious than recognizing that the energy rate density of a human bone is not indicative of the ERD of the entire organism; in both cases the researcher must keep expanding their scope until they have a full view of the whole system.

As a systems-based matrix the measurements of ERD can be freely adjusted to encompass different combinations of factors, for instance the ERD of systems or events

19 Eric Chaisson, "The Life ERA: Cosmic Selection and Conscious Evolution," *Faculty Publications*, January 1, 1987, http://scholarship.haverford.edu/astronomy_facpubs/70.

can be combined with the ERD of the host environment to find the complexity of biospheres, planetary systems, broad interstellar phenomena, etc.[20] This organization of complexity focuses on holistic qualitative information, with an expected significant increase in ERD to 10^3 when observing conscious systems.

CONCLUSION

In establishing an interdisciplinary, non-anthropocentric paradigm for identifying new conscious systems, a set of three main factors have been established, each with their own traits and characteristics: communication, adaptation, and complexity. These factors are universally applicable and as divorced from biological preconceptions as is possible for a human mind. It is intended that this approach will help to expand concepts of what may or may not be a conscious system beyond the current scope of individual disciplines.

While the detailed research into the implications of this paradigm must involve specialists in the various fields to be explored, the potential applications are striking. An initial examination of the Gaia hypothesis under the conscious systems paradigm reveals that Earth's biosphere meets the first two factors (communication and adaptation), but only reaches a complexity of 10^2. However, if intelligent social structures and technology were included as part of the planet's complex adaptive system rather than separate from it, Earth easily qualifies as a conscious system.

It is hoped that conscious systems theory will help illuminate the potential for pervasive conscious systems beyond the human sphere.

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20 Timothy M. Lenton and Marcel van Oijen, "Gaia as a Complex Adaptive System," *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 357, no. 1421 (May 29, 2002): 683–95, doi:10.1098/rstb.2001.1014.