Complex-Information Ethics Theory

Ken Solis
M.D., M.A.

Correspondence | drjump76@gmail.com

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ABSTRACT

If ethics is of any interest to big historians, it might be primarily for analyzing the "ought to haves" and the "ought not to haves" of prior large scale human actions, e.g., does an agriculture-based lifestyle cause more harms to humans overall as compared with a hunter-gatherer lifestyle? However, big historians are also often concerned about the future events of Earth that can be influenced by humans, such as climate change, mass extinctions, and the predicted technological singularity. Because those concerns encompass both human and non-human complex systems such as the biosphere and possible future advanced artificial intelligence, big history requires an ethical framework that addresses anthropocentric as well as non-anthropocentric concerns and perspectives.

Complex-information (C-I) ethics is a new information-centric theory described in this paper. Several other information-centric variants have already been proposed. However, C-I theory seeks to enhance, broaden, and deepen this genre of ethical theory with the general directive that moral agents should perpetuate and enhance net positive deep informational artifacts and processes. Before introducing this directive, however, we will first explore and define its underpinnings in the disciplines of thermodynamics, information theory, and complexity science. By better understanding how entropy and its Janus-like counterpart, information, are relevant to C-I's ethical directive, we can also better appreciate why complex systems, as defined by their key characteristics, have intrinsic ethical value. We will also examine why artifacts and processes with deep semantic value can have instrumental ethical value to agents. Although many, if not most, complex systems are ethically and pragmatically worthy of being perpetuated and enhanced, some are not because of their negative effects on the broader complexity landscape. A couple of important caveats to C-I's directive are also described.

By bringing the findings and analytical tools of key physical sciences to bear, C-I theory opens new avenues for exploring what we as moral agents ought and ought not to have done in the past, as well as what we ought or ought not to do presently and in the future. This class of ethical theories also delineates some of the primary bridges from the natural and physical sciences to the more subjective realm of philosophical ethics.

Big History—Do We Need Ethics?

Ethics is the subdiscipline within philosophy that, stated in different ways, is concerned about what we ought versus ought not to do, or what is the Good versus what is the Bad. While a knee jerk response might be, "Yes, of course, big historians should be concerned with doing the right thing," a little more reflection might question, "what does ethics, especially formal philosophical ethics, have to do with the study of past events or even possible future events?" That is a fair question. After all, historians are generally more concerned what happened rather than doing a deeper ethical analysis of what should have been done by moral agents (those capable of making ethical decisions): we cannot rewrite history. Also, ongoing or near future events, like global warming and mass extinctions, do not seem to require a profound ethical analysis to decide whether humans ought or ought not to try to prevent these major events from occurring. A little more thought, however, exposes that even behind apparently obvious courses of desired action lurk many subtler ethical dilemmas. For example, should we try to save a rare obscure plant at the expense of losing agricultural land? It is difficult to be an environmentalist if you and your children are hungry. Should developing countries forego CO_2-producing industrialization despite its material benefits when developed countries have already largely contributed to global warming? Should artificial intelligence be given rights, and if so, at what level of "intelligence"?

These examples reveal at least a few reasons why we should have an interest in ethics: big historians often have a unique knowledge base, given our interest in vast spans of time, familiarity with multiple disciplines, and examination of overarching trends. With that unique background we are ostensibly well positioned to offer unique perspectives to assess the ethical dimensions of prior human events, current generalized human actions, and possible future actions and scenarios. The current COVID-19 pandemic offers but one contemporary example where historians can provide lessons regarding how societal dynamics and the viral pathogen itself will likely unfold. For example, the Spanish flu pandemic of 1918-1920 was met by public mask burning protests, the continued gathering of large groups of people, and healthcare systems being overwhelmed; many politicians minimized the disease's extent and severity (Barry 2005). These actions led to confusion, loss of trust in government, and needless deaths. Arguably, the same mistakes were made yet again with essentially the same ethical ramifications. For example, how should we balance personal freedom versus the welfare of the community? How should we fairly distribute limited healthcare resources? What is the role of governments and communities in facing a common, invisible threat?

Ray Kurzweil's predictions from his book, *The Singularity is Near*, provide an example where big historians might offer ethical lessons from the past to anticipate the future better. Kurzweil foresees a future utopia made possible by advanced artificial intelligence and nanotechnology (2006). Big historians, however, would likely urge strong caution about having unequivocal hopes regarding these new technologies and likely advise that we should proceed with due diligence. While "hope springs eternal," we can point out that every increase in complexity, whether it is the change from hunter-gatherer to agrarian societies or the onset of the information age, new sets of unanticipated problems invariably have occurred. Big history has likely never witnessed an unmitigated panacea with any wide-ranging change or advancement.

Ethics—Which One?

The classical, well-known ethical theories that have been promulgated by philosophers, religious leaders, and other thinkers over the past few millennia have almost universally been concerned with what was the right action to take for the sake of themselves and other humans, i.e., they are anthropocentric. Traditional theories like Aristotle's (384-322 BCE) virtue ethics focus on what human character traits would promote human flourishing (eudaimonia). Immanuel Kant's (1724-1804) deontological ethics states that we should faithfully follow rules that any rational human being would develop to avoid contradiction, hypocrisy, and other irrational practices, as well as have the qualification that the rules should be universalizable, i.e., followable by everyone. Jeremy Bentham (1748-1832) and John Stuart Mill's (1805-1873) utilitarianism argues that we should do the action that would lead to the greatest good for the greatest number of people (Panzas et al. 2010). This list is far from complete; nevertheless, with some exceptions like Jainism, most religious ethical codes and secular ethical theories are similarly anthropocentric (Mardia 2013).

With increasing awareness of the environment and its importance in the last century, ethical frameworks reaching beyond immediate human concerns have been proposed to include other living organisms, ecosystems, and Earth itself. A couple of examples include Aldo Leopold's (1887-1948) land ethic and Arne Naess's (1912-2009) deep ecology (Aldo Leopold Foundation 2021; Keller 2008). The unwritten, informal ethics of many Native American tribes expresses deep concern about their relationship to nature and long preceded those of Western thinkers (Reynolds 2007).

The latter theories that give ethical value to the biosphere are an important step in the direction of ethics being concerned about entities outside that of immediate human concerns. After all, Earth did and can do just fine without us (and in many ways did better). We, however, cannot do without Earth and its irreplaceable biosphere. Even ethical theories that include the biosphere, however, do not provide any framework in which to address other ethical issues that we might face in the future. Advanced self-aware artificial intelligence, as proposed by Kurzweil, and the possible discovery of extra-terrestrial life are examples of entities that arguably have significant ethical value beyond what is useful for humans. Some theories that have a framework with which to address these potential new scenarios have been developed in recent years. Floridi's information ethics, Freitas's thermoethics, Maxwell's complexity ethics, Vidal and Delahaye's universal ethics, and Doyle's information-based ethics all propose to broaden that which has ethical value to systems that are concerned with informational content in the physical sense, or complex systems (Floridi 2006; Freitas 2008; Maxwell, n.d.; Vidal et al. 2018; Doyle 2016).

Of course, increasing complexity is one of the—if not *the*—overarching themes in big history. Anticipating and accommodating ethical issues relevant to other complexities, anthropocentric or not, is another desired feature for big historians. Before describing complex-information ethics, which I have developed over the past ten years or more, I would like first to look at the foundations upon which it and other similar theories are constructed. Although many readers might already be familiar with many aspects of these foundations, the definition and explanation of pivotal terms like *entropy*, *information*, and *complexity* can vary significantly from author to author. Hence, it is important for me to set C-I theory's particular foundation carefully. As the philosopher Socrates is quoted to have said, "The beginning of wisdom is the definition of terms."

Entropy—"The Devil"?

Increasing entropy is an inexorable and ongoing, fundamental process of the universe, and it is part and parcel of the second law of thermodynamics. This law has myriad articulations because the results make themselves known in various ways depending upon the focus. For example, a chemist will be interested in knowing whether a chemical reaction will occur spontaneously (i.e., occur without a net input of energy). If the reaction results in an increase in entropy, then the answer is "yes." A mechanical engineer, on the other hand, might be more interested in the second law's assertion that some energy involved in any process will not be available to do work but will irrevocably be lost to increased entropy—typically in the form of heat. She will then try to design a machine that maximizes the amount of energy that is available for work while minimizing that lost to heat so that it is more efficient. For the purposes of this paper, however, we will focus on what is perhaps the most understood aspect of the second law, which states that "[t]he entropy of the universe increases in the course of any spontaneous change," i.e., for any action or change that occurs, the overall entropy of the universe can never decrease (Atkins 2010).

As with the second law of thermodynamics, its key term, *entropy*, also has many different articulations because the results of entropy have varied manifestations. Most commonly, an increase in entropy is described as the inevitable trend of any system to progress from being ordered to disordered (e.g., things fall apart over time). Although describing entropy as "the degree of disorderliness" closely approximates its character, it is not rigorous enough for our purposes. (There are a few instances where an increase in disorderliness is not readily apparent.) Instead, a more accurate definition is this: *entropy is the logarithm (log) of the number of possible microstates that constitutes a system's macrostate* as described by the equation, $S = k \log W$, where S is entropy; k is Boltzmann's constant in the units of joules per degree Kelvin; and W is the number of microstates for a system's macrostate (Atkins 2010). This definition and equation, which was first described in the latter 1800s by the Austrian physicist Ludwig Boltzmann (1844-1906) and elaborated further by the American physicist Willard Gibbs (1839-1903), might sound obtuse. However, we can use a hypothetical teen's bedroom to explain the jargon in more parochial terms.

As a metaphor, we will state that a teen's bedroom represents a system. The room's overall condition, in turn, represents its macrostate. The furniture, apparel, garbage, and other articles metaphorically represent its microscopic constituents, and one particular arrangement of these articles represents one microstate. When the bedroom is in a macrostate of tidiness, its articles are all placed where they should be, including the dressers, bed, desk, lamp, apparel, and any garbage placed in the trash can. Importantly, the number of possible microstates where the room's macrostate is still tidy are many because the various articles can be moved around or rearranged to a certain degree, and the room would still be tidy. For example, the room is still tidy if the socks are placed neatly together but in a different drawer, the bed has been moved a couple of centimeters, the garbage is in the trash but in a different arrangement, and so on. In the end, there are numerous possible microstates where the room has a macrostate of tidiness. However, the number of possible microstates where the articles are disordered and the room is messy is many magnitudes more enormous. Because a tidy room has comparatively few microstates, it is also described as being in a low entropy state, whereas a messy room is in a high entropy state. A room unfortunately destroyed and scattered about by a tornado would be in a state of maximal entropy.

Figure 1. The abstract phase space of a tidy room (lower entropy) is much smaller in area than the phase space of a messy room (higher entropy). One arrangement of the room's articles is represented by one point (the red dot) within their respective phase spaces. Note: The phase spaces are not drawn to scale. The phase space of a messy room would be much, much larger in comparison to the phase space of a tidy room.

An important concept and visual tool that will be relevant for our ongoing discussion is the idea of *phase space*. A phase space is an abstract area, whose size is proportional to the number of possible microstates that constitute a system's macrostate. Figure 1 represents the hypothetical phase space of a tidy room versus a messy room, where some point in each phase space would, in turn, represent a very particular arrangement of the room's articles. If drawn to scale, the phase space of a messy room compared to a tidy room would be much larger in area than would fit on a sheet a paper. The phase space of a room destroyed by a tornado would be many magnitudes larger still.

Of course, the pioneering physicists who pondered the nature of entropy did not think in terms of a tidy versus a messy bedroom. Instead, in a more typical physics example, a system might be a one-liter container of air molecules whose macrostate is described as having one unit of atmospheric pressure and a temperature of 20 degrees Celsius. That macrostate is in turn physically determined by a range of locations, densities, and velocities of the container's microscopic air molecules. The size of that range is again proportional to the size of its phase space.

Norbert Wiener, the twentieth-century mathematician of cybernetics fame, was perhaps the first to see that entropy is a correlate to the Bad, and that information is a correlate to the Good, when he remarked in his 1954 book, *The Human Use of Human Beings*, that (Wiener 1954)

> [t]he scientist is always working to discover the order and organization of the universe, and is thus playing a game against the arch enemy, disorganization. Is this devil Manichaean or Augustinian? . . . Just as entropy tends to increase spontaneously in a closed system, so information tends to decrease; just as entropy is a measure of disorder, so information is a measure of order.

Why did Wiener call entropy "this devil" (and often times, "the arch enemy")? Figure 2 helps to demonstrate his reasoning. If we use the analogy of teenagers' rooms or even more simply, triangles becoming more disordered (higher entropy) from left to right, we can equate that to a system becoming less well. The phase space also increases as a system

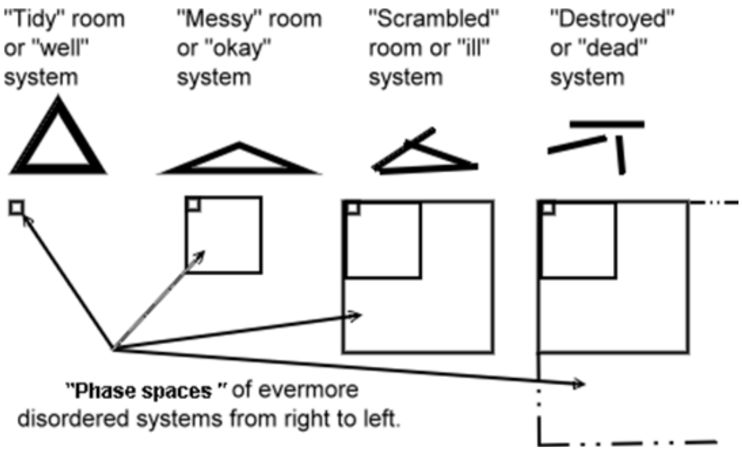

Figure 2. Each column abstractly represents a system that is progressively less ordered, or higher in entropy as one goes from left to right. Consistent with its degree of order, each triangle is progressively less restricted in its relationships until it is destroyed at the far right. The equilateral triangle on the left is most ordered, and its phase space is smallest as well, as depicted by the small square. There are a greater number of possible relationships and larger phase spaces as the triangle progressively fails. Analogously, for any "well" system, whether it is a tidy room or a healthy person, there are fewer ways for its constituents to be in relationship to each other than when they are less well. Note that the phase spaces are not drawn to scale but should be successively much, much larger.

becomes less well because the number of possible microstates for an ever more failing system becomes ever greater. In other words, there are ever more ways for a room to become haphazard or for a triangle to lose its geometry and become a less well equilateral one. Hence, more entropy correlates with a "bad" state.

Of course, according to the second law of thermodynamics, an increase in entropy must occur somewhere in the universe for any process to occur, including the processes that keep a system well. For example, you must eat, digest, and metabolize food to stay alive—never mind healthy. An increase in entropy had to occur with each step of the processes. Therefore, entropy is also an unavoidable Good—but then, every story needs a villain!

As noted in his earlier quotation, Wiener also stated that information, or order, is the obverse of entropy, which implies that it is a force for the Good—the hero in our story if you will (Weiner 1954, 21). How is it that information and order are equivalent? Let us look briefly at the fundamental nature(s) of information itself.

Information about Information

Before we make the claim that information is the equivalent of order and forms the basis of the Good, we need to look carefully at what underlies this seemingly ephemeral term. Terrence Deacon (2011), a neuro-anthropologist at University of California, Berkeley, importantly pointed out that much of the confusion regarding the nature of information is because "[t]his term is used to talk about a number of different kinds of relationships, and often interchangeably without discerning between them." I concur with his assessment as well as his way of parsing the main types of information used in everyday discourse: (1) syntactical; (2) semantical; and (3) pragmatic (more commonly called "surprise" as noted below).

Syntactical Information

The terms *syntax* and *syntactical* are used most often in the context of grammar, where it refers to how words are ordered in a language. The dictionary definition of *syntax*, however, is not restricted to language, but refers to how things in general are ordered or, more generally, how they are in relationship to one another. Those things can include atoms in a molecule, planets in a solar system, the living organisms of a temperate forest, individuals in a society, and . . . words in a sentence. Syntactical information also underlies the other types of information that will be described later. Not everyone who contemplates the underlying nature of information concurs with Wiener that information is fundamentally a measure of order or relationships. He and I have good company, however. That company includes Benjamin Schumacher, a physicist, quantum information authority, and protégé of the late famous physicist John Wheeler (1911-2008), Luciano Floridi, who is a leading professor of Information Philosophy at Oxford University, and neuroanthropologist Terrence Deacon. (Schumacher 2015; Floridi 2015; Deacon

2011). My own definition of (*syntactical*) *information* is "the relationship of entities in spacetime." I added "spacetime" to the definition because the fate of information in or on the surface of black holes—where the rules of physics are often conjectural— is not yet clear to physicists.

A hypothetical example can illustrate why relationships between things (a.k.a. relata) is synonymous with information. Imagine that you want to inform someone about a particle's location in otherwise empty spacetime—about the simplest kind of information that you could offer to someone. Unless that particle's location is in relation to something else, you cannot provide them with that (syntactical) information. You must give its physical location $X_{A,}$ Y_A, Z_A in relation to something else, such as the center or some boundary of that space; its position relative to particle B; or something mundane like three blocks west, two blocks south, and five stories above the street level of the Chrysler building in New York City. In fact, without particle A's being in relation to something else, you cannot even inform someone whether it is moving or not moving; it moves only in relation to something else. Similarly, with regard to informing someone about the particle's location in time, T_a, you also need to give its relation to another event in time, such as when Rome was legendarily founded or when Jesus Christ was believed to have been born. Even to inform someone that "John is happy" is to inform another indirectly and implicitly that happy is an emotional state relative to when he feels "okay" or "sad."

Many other key attributes of syntactical information were especially more deeply understood after the 1948 publication of a seminal paper, "A Mathematical Theory of Communication," by the mathematician-engineer Claude Shannon (1916-2001). Working on a task assigned to him by his employer, Bell Labs, Shannon quickly understood that an engineer needed to worry about only the syntactical information (i.e., the ordering of signals comprising a message) that was transmitted, not the meaning of the information. His paper is widely considered by scientists, engineers, and science historians to be one of the most important of the twentieth century because it introduces many concepts that helped to usher in the Information Age. His information theory introduced many concepts now taken for granted, such as the signal-to-noise ratio, the use of Boolean logic for computer operations, and other pivotal insights that helped to conceive and develop the information technologies of today.[1]

Most importantly for our purposes, Shannon also determined that syntactical information can be mathematically measured in units that he called bits—a contraction of binary digits (a numbering system limited to using 0's and 1's). The amount of syntactical information of a message is determined by the formula $H = -k \log_2 M$, where H is the amount of information in bits, k is a constant for adding the unit of bits, and M is the number of possible messages. (Note: in this formula, each message has an equal probability of occurring. Measuring information where messages have varying probabilities has a slightly more complicated formula, but that does not change the following discussion in any substantial way (Schumacher 2015).

This mathematical equation also helped to reveal syntactical information's relationship to thermodynamics' entropy whose formula, $S = k \log W$, was noted earlier. These equations are the same in form except for the negative sign. This difference importantly reveals that information is mathematically, as well as conceptually, the antithesis of entropy. The ramifications of the Janus-like nature of entropy and information has been borne out in other ways and fields as well—too many, in fact, to recount in this article.[2]

Semantic Information

Semantic information is typically defined as "information that has meaning or purpose to an agent" although other more complicated definitions have been proposed by others as well (Zhong 2017; Floridi 2005). Semantic information is, therefore, dependent on apprehension, processing, and interpretation of syntactical information by an agent for its realization. It is typically difficult for us to quantify semantic information mathematically, except the subtype called informational "surprise," which will be discussed in the next section. A semi-quantitative exception is semantics with which we can add qualifiers like incredible, deadly, life-sustaining, large, or other adjectives that belie the relative importance or magnitude of the message.

Nevertheless, there is not currently, and perhaps never will be a mathematical equation to determine the degree of semantical information present. For example, the novel *Moby-Dick* might quantitatively and qualitatively have a much greater amount of semantic information than the back of a cereal box, but we are not able to attach a derived number of bits of semantic informational content to either.

Although semantic information has meaning or purpose for an agent, it need not rise to the level of awareness for an organism. Simple life forms like bacteria might chemically sense nutrients in one direction and a noxious substance in another direction. Through a series of complicated but hypothetically traceable chemical reactions that end in the movement of its flagella or cilia, it would then move toward a nutrient (meaning = sustenance) and away from the noxious substance (meaning = danger). Even for higher organisms with advanced brains, information can have semantic content that the agent is not aware of or ignores. In the former case, the usually unconscious act of breathing is driven by the semantic information derived from the blood's pH, carbon dioxide, and oxygen levels.

For organisms with nervous systems, and especially those with advanced central nervous systems (i.e., brains) like dolphins or humans, how syntactical information is processed so that we are aware of that meaning remains a daunting and, for the foreseeable future, impregnable challenge to understand on the level of physics, chemistry, and the biological sciences. The philosopher David Chalmers labels this "the hard problem" because science does not have the tools, methods, or even a hypothetical basis on which it can explain how matter/energy—and I would add, fields of force—can eventually manifest these and other higher mental phenomena like consciousness, abstract thinking, and, I think he would include, moral decision making (Chalmers 1995). For problems like the apprehension of semantic information, consciousness, and even the origins of life, known physics can provide us with some boundaries or necessary conditions, but it is insufficient to explain fully how these phenomena become manifest. In other words, although thus far no living processes have been demonstrated to conflict with known physics, we are still especially far short of explaining the physics of higher mental phenomena.

Surprise Information

Claude Shannon, the founder of information theory, believed that a consensus on the real meaning of *information* would be unlikely. In that regard, he is correct thus far. There is still no universal agreement on what information ultimately is although others and I assert that it is fundamentally the relationships between things, or relata, as explained above. Shannon's own stated belief about information's character is that it is "that which reduces uncertainty" and called this reduction the "surprise" of information (Stone 2015). Relationships that are known can be viewed as information that reduces the uncertainty of how things are extant relative to other things, i.e., the more you know about something's relationships, the less uncertainty you have about them. Conversely, increased entropy results in a diminution of set relationships and an increase in uncertainty about them.

To illustrate how a message can have surprise information that is both demonstrable and measurable, we can use the storied example of how Paul Revere and other riders learned how the British troops were going to travel to Lexington: one lantern was to be lit in the Old North Church tower if they were traveling by land, two if by sea. When they saw two lanterns lit, the informational surprise of how the troops were going to travel was reduced by fifty per cent—the same as learning which side of a coin lands up. Of course, many examples are more complicated than this simple one and can require a little more math to determine the message's surprise. The simplest version of the surprise of a message is this: $s(x) = \log_2 [1/p(x)]$, where s(x) is the surprise of a message as measured in bits, and p(x) is the probability of each message (Stone 2015). In the Old North Church tower case, $s(x) = \log_2 1/ ½ = \log_2 2 = 1$ bit. Hence, the riders gained one bit of information when they saw the two lanterns in the tower or, expressed in another manner, had their uncertainty reduced by one bit. If the probability of a particular message is small, then subsequently receiving that message increases its surprise. For example, burglar alarms are quiet the vast majority of time. If the alarm sounded off for one minute only once every ten years (~5,256,000 minutes), the surprise of its going off would be $s(x) = \log_2 1/ 1/5,256,000$ or $\log_2 5,256,000 \approx 22.3$ bits. The number of bits might seem small given the intuitively large amount of surprise that would occur if the alarm sounded, but logarithms make even large numbers more manageable.

Complex-Information (C-I) Ethics — A New Perspective. The Good is . . .

The preceding discussions have laid the groundwork needed for a line of argument that the Good can be based on that which is not necessarily dependent on human interests, i.e., non-anthropocentric. C-I theory grounds its values on that which inherently has deep syntactical informational content, or that which is imbued by agents, with a metaphorically deep amount of semantic information. Other authors have also argued for an association between information or relationships and the Good and, conversely, increased entropy and the Bad. C-I theory, however, seeks to broaden, further define, and clarify this genre of theory. To the point, C-I theory's central claim *is* that "[t]he 'Good' is that which perpetuates or enhances net positive, deep informational artifacts and relevant processes." Even with the foregoing discussions on entropy and information theory, this ethical rule begs to be further explored and explained.

Deep Informational Artifacts and Processes

The discussions of the second law of thermodynamics and information theory above set the stage for what we mean by *deep informational artifacts and relevant processes*. I proceed by describing how each of the three different types of information leads to artifacts or processes that are construed by and relevant to C-I ethics.

That with Deep Syntactical Information, i.e., Complex Systems

As discussed earlier, syntactical information generically refers to the relationship of things (a.k.a., relata) and makes things possible. Without relata, all that is present is the equivalent of the cosmic background radiation—random photons everywhere at essentially the same temperature. At syntactical information's most superficial level, we encounter fundamental structures as when different quarks relate to each other to form protons, neutrons, and other subatomic particles. At its deepest level, various relata occur to manifest complex systems, including living organisms, ecosystems, stock markets, the immune system, and human society. Complex systems (a.k.a. complexities) are syntactically deep because they are built upon many layers of relata: quarks to nucleons, nucleons plus electrons to atoms, atoms to molecules . . . cells to tissues, and ultimately, living species, soil, oxygen, water, etc., to the biosphere. This degree of hierarchy was proposed by the polymath Herbert Simon (1916-2001) in 1962 to measure the degree or depth of a system's complexity (Mitchell 2009, 109).

Authorities in the discipline of complexity science, which was arguably formalized in 1984 with the founding of the Santa Fe Institute in New Mexico, USA, have subsequently developed metrics for determining a system's degree of complexity. Unfortunately, these and other metrics, including Eric Chaisson's "free energy flow rate density" of which many big historians are familiar, all have significant shortcomings (Chaisson 2001). Although few would deny that the human brain has greater complexity than a bacterium or an ant colony, it is not clear that any metric would be able even to semi-quantify and compare the complexity of New York City or a temperate rainforest.

Complexity science also has been unsuccessful in formulating a concise universally agreed upon definition for complexity although, again, many have been proposed (Mitchell 2009). These limitations might not seem to bode well for an ethical theory with *complexity* in its very name. However, there is much broader support for the characteristics necessary for complexities to be extant. Besides having deep syntactical content and processes, the following criteria are almost universally agreed upon as being required for a system to be recognized as complex (Mitchell 2009; Johnson 2007; Page SE 2009; Ladyman et al. 2012; Waldrop 1992; Gribbin 2004):

1. A complex system consists of multiple interactive components, or agents, that exchange and process information without a central control. A classic example of this process is a flock of birds or a school of fish that move in shifting formations without a central leader. Instead, each bird or fish, who is an agent, follows rules regarding proximities to its neighbor. The lack of central control extends to other complex systems, including brains and societies. Even though you might think that you are the agent in control of your brain, different assemblages of neurons are, in fact, carrying out a myriad of functions like respiration, digestion, circulation, balance, sensory processing, etc., without your awareness, never mind control. Similarly, even the most totalitarian government cannot manage every aspect of the members of its society.
2. Complex systems are dynamic and, therefore, require energy flow. *Dynamic* is a technical word for *changing*. Static systems like a parked car might not do anything interesting except decay with time (entropy again). Dynamic systems, however, have interactions both internally and externally with their environment, which require work energy to accomplish.
3. Their structure and processes are neither too ordered, as with a quartz crystal, nor too random, as with a room of air molecules. Instead, they exist somewhere between these two extremes.
4. They exhibit patterns of behavior that would not be predicted from the behaviors or characteristics of their more fundamental components. The phenomenon is usually referred to as "emergence." For example, no matter how much you studied a neuron, even a super-physicist-biologist-neuroscientist would not predict that a collection of them put together in just the right way could eventually manifest an individual who has self-awareness, might write songs, and solves math problems. An emergent phenomenon can be abstractly represented as A+B→C, where some relationship that occurs between its components, represented as A and B, yields an emergent product, C. The interacting components of a non-complex system, however, usually result in a simple summation or conjunction that could be represented as A+B→AB, where AB might be a new entity but has no unexpected properties.
5. They self-organize and self-regulate their structure and processes. These operations also require free energy flows.
6. They exhibit non-linear behavior that makes their behavior and even future structures difficult to predict; i.e., for any given input, the resulting output is not determinate, but statistical.
7. Additionally, most authorities in complexity science include adaptation as a requisite criterium or will divide complex systems into non-adaptive complex systems (e.g., stars, hurricanes) and adaptive complex systems (e.g., living organisms, the global Internet). In this context, adaptation means that something can alter itself or its progeny so it improves its function, or so it is more likely to persist despite changes in its surroundings. Adaptation also serves as a bright line for complexity because only life and systems derived from it attain this quality, whereas non-living entities and their derived systems persist or do not

persist according to the more fundamental laws of nature. For example, stars might last many billions of years, have countless interacting parts, and have emergent properties like nuclear fusion and the creation of new chemical elements; however, they do not alter their structure, processes, or progeny to survive a changing environment better.

The proposition that complexities should be perpetuated implies that even passively allowing the loss of complexities like the panda bear, a rainforest, or a threatened native tribe is an event to be avoided. The act of enhancing complexities is consistent with historically ethical desired states such as happiness, health, flourishing, and the like. A complexities state of being well also adds informational depth because the specified order is increased. Conversely, failures of complexities' key relationships have been equated with the Bad such as death, sadness, suffering, disease, crime, and war to name a very few. There are many more ways for a complexity to be unwell because the range of failing and failed relationships amongst its constituents and the concomitant phase space is larger just as it is when a room is more disordered or a triangle loses its geometry.

Although I began working on C-I theory years ago, it is not the first theory to identify complexities and the wellness of complexities as a Good. Universal ethics as developed by Belgian philosopher, Clement Vidal, and physicist, Jean-Paul Delahaye, has a very similar articulation (Vidal et al. 2018). To paraphrase, universal ethics states that the Good is that which preserves, augments, and recursively promotes organized complexity. Their statement is synonymous with perpetuating and enhancing complexities, and I must acknowledge their precedence in publication and possibly in conception. One important way in which the theories differ, however, is *how* complexities are identified. This difference leads in turn to a substantially different list of what entities constitute a Good. Universal ethics relies on a metric for complexity called logical depth (LD), which was developed by the physicist and information theorist, Charles Bennett (1943-). As noted, all metrics are too flawed to be a reliable means of measuring complexity, never mind identifying them. Indeed, Bennett himself wrote that the logical depth was meant as a *measure* of complexity (Bennett 1988). I will discuss other problems regarding the use of this metric as well as acknowledge other similarities to and differences from related information-based ethics, as appropriate.

Why are Complexities a Good?

Universal ethics notes that various qualities that are indicators of a well complexity like health and happiness are widely considered Goods throughout philosophical history (Vidal 2018). A state like Aristotle's eudaimonia, which translates to *flourishing*, is a better catchall term because complexities like ecosystems do not experience the emotion of happiness, and it is metaphorical to state that the global economy is healthy. Nevertheless, their point is valid.

Still, why are complexities an important, even the predominant Good that morally deserves to be well and that is not dependent on its value to humans and thereby has great intrinsic value? The overriding reason is because if there are no complexities, then there are no ethical agents, hence, no ethics to be discussed at all. The practice of ethics requires advanced agents that are capable of moral decision making with the ability to project how their actions will affect themselves as well as (often) multiple other complexities' well-being. The ability for such abstract predictive and weighted thinking appears to be a capability of only a few advanced animals such as humans, likely our evolutionary predecessors, and a few mammals with advanced brains such as chimpanzees, dolphins, and elephants (De Waal 2006). Furthermore, moral agents like humans are dependent for their survival on other complexities like societies, ecosystems, and ultimately the biosphere. The wellness of those systems in turn affects the wellness of moral agents. In the end, complexities have intrinsic ethical value that is not dependent on their utility to humans or even other moral agents because they are prerequisites.

Of note, other systems that are less complex—perhaps even not complex by anyone's metric—but still necessary for a moral agent's existence like the sun, physical Earth, atoms, and the universe itself are not ethical patients. With our current and foreseeable technologies at least, we cannot in any significant way do actions that would affect these entities' existence or state of being. As recent events demonstrate, however, even a large complexity like the biosphere is an ethical patient because it can be adversely affected by our actions.

The Good of Other Types of Informational Artifacts and Processes

While artifacts and processes with deep syntactical information like a tallgrass prairie, summed social interactions, or bonobos have intrinsic ethical value, those with deep semantic or surprise information have extrinsic (a.k.a. instrumental) ethical value. An artifact like a claimed holy relic and a process like a Catholic liturgy has meaning, sometimes with ethical implications, to its devotees. Similarly, a Gutenberg Bible or a new important scientific discovery has deep informational surprise that is given value by agents. Syntactically, however, the information of a Gutenberg Bible or a shard of an alleged bone from Saint Thomas is not complex and is just there. As a litmus test, you can ask what value an extraterrestrial intelligence would assign an artifact or process without knowing more than that of which it is constituted and how it behaves.

Universal ethics claims that these and other items like music symphonies, award winning novels, and computer microprocessors are all complexities because they are syntactically deep as determined by their logical depth (Vidal 2018). However, it is a mistake to use solely logical depth (LD) to classify things as being complex for several reasons:

- As discussed, every metric proposed for measuring the degree of complexity is flawed. In the case of LD, there is "typically no practical way of finding the smallest Turing machine that could have generated a given object, not to mention determining how long that machine would take to generate it" (Mitchell 2009). Also, it is not typical for authorities to use a metric alone to determine whether a system qualifies as being complex. The only way in which artifacts and processes can count as being complex via LD is if the informational content of the creator is included. Extending the computational boundary this far, however, potentially makes all artificial artifacts more complex than the very complexity creating them, e.g., the LD (microprocessor) = LD (humans) + LD (microprocessor).
- The artifacts listed by Vidal and Delahaye as being created by humans and being complex fail to meet the nearly universally agreed upon criteria for even being non-adaptive complex systems. For example, even a symphony by Beethoven and advanced computer microprocessors are not self-organizing, composed of multiple agents without a central control, and so forth. Admittedly, some artificial systems do qualify as complexities, such as global economic trade and even (arguably) an improvisational jazz band. However, they qualify via their characteristics rather than computational time needed for their creation.

Again, a good litmus test for determining whether something can be classified as being complex is to take the perspective of an alien intelligence. If a Rafael painting or a Nobel prize winning novel were placed before it, would it proclaim that it had come upon a complex system? Without knowing our culture and its products, it would more likely state that it saw a canvas with pigment or papers with inked markings, respectively.

This paper is not meant to be a polemic against universal ethics. Indeed, I am indebted to Vidal and Delahaye's observations and analyses that had escaped my attention. As a case in point, the name for this ethical theory was simply "complex ethics" before their paper made me realize that semantic and surprise information could also be ethically relevant, hence, the hyphenation and inclusion of the term *information* in complex-information theory.

Semantic Information—An Instrumental Good

We value many artifacts and processes because we imbue them with great meaning or purpose. In the lexicon of information, they have great semantical import to us. Some artifacts and processes have deep syntactical content as in the case of a Beethoven symphony. Others like a Christian cross, the Japanese flag, or a Catholic eucharist are simple syntactically but still hold a profound (metaphorically deep) meaning to their adherents. The meanings of these artifacts to their adherents are great enough that witnessing the artifacts being maligned in some manner can cause them anger, anguish, or both. We could forgive those who were not familiar with what these artifacts represented if they burned a Christian Cross's wood to keep warm, spread a national flag as a tablecloth, or interrupted a eucharist. After all, their value is extrinsic to the things or processes themselves and instrumental to only those who understand their abstract value.

Novel Information—Another Instrumental Source of the Good

Some Goods are deeply (a metaphor again) valued by humans for an important subset of semantic information that is worthy of consideration: they are either rare or they provide new knowledge or experience, i.e., a new understanding about relata. Recall that Shannon's surprise of a message is a measure of how unexpected that message was to its recipient; and the formula for measuring that surprise is $s(x) = \log 1/p(x)$, where $s(x)$ is the surprise measured in bits, and $p(x)$ is the probability of that message occurring. Therefore, messages, events, or other things that occur rarely are reflected by its surprise being consequently large. The informational surprise of finding life in the universe will be enormous, not just psychologically for us, but even from a purely physical-mathematical perspective because the vast majority of the universe is empty space; just a tiny percentage of mass consists of potentially life-sustaining planets—the remainder of the mass being inhospitable stars, nebulas, gas giants, black holes, and possibly dark matter.

Claude Shannon expressed the surprise of a message as being a way of how much it reduces one's uncertainty regarding some question. Similarly, science and other disciplines work to understand the laws, states, processes, etc. of the universe better. A new discovery reduces our uncertainty about some aspect of the universe, and some of these findings can have ramifications for our well-being or the well-being of other complexities and, therefore, have ethical value. A new medical treatment might mitigate pain or improve the chances of curing a cancer; a pioneering insight into thermodynamics or material science might provide a new source of sustainable energy; and a new microprocessor design or computer software program might make it possible to design a vaccine to cure distemper—a virus that is killing the endangered African wild dogs. Discoveries with sufficient import to have ethical value need not be limited to the sciences. New philosophical and political science perspectives and treatises have helped to promote the equality of all humans: the condemnation of slavery, the rejection of the subordination of women, and improved the status and rights of those in the LGBTQ community. New historical revelations might help us to navigate the future better; for example, the lessons gained from Rapa Nui offer a real lesson of what can happen when humans overstress their local environment. This list is, of course, far from complete.

Surprise or novelty can also be a measure of rarity, and something rare can become an increased Good, especially if it is not reproducible. The forty known Gutenberg Bibles, two hundred forty-four Stradivarius violins, rare Ming vases, and the single sculpture *David* by Michelangelo are all examples of non-reproducible rarities that are also important semantically to us because of their historicity and aesthetics (*Britannica* 2021; *New Violinist* 2021). Intentional damage or loss to any of these artifacts would be a wrong significant enough to make international news and result in collective human angst.

Combining Information Types

An even more elevated Good can also be achieved by combining that which has a high degree of complexity (syntactics), meaning or purpose (semantics), and rarity (surprise). If we find the recently confirmed extinct ivory-billed woodpecker, it would be a great surprise both emotionally and mathematically, have great meaning to birders, and, of course, have deep syntactical content because it is a complex organism (Del-Colle 2021). Empirically, if not ideologically, society also seems to value some people more than others. If John or Joan Doe dies, their passing will likely be listed in the local newspaper's obituary, and their circle of friends and relatives will attend the memorial services because their relationship with the deceased had great meaning. While John or Joan was also truly unique in the strictest sense of the word, they might not have been so unique as a head of state, major religious leader, famous movie actor, or gifted athlete of a popular sport who dies. The nation and even the rest of the world will note their passing in the news, perhaps a biographical movie will be produced, and an executive order might be issued to fly the national flag at half-staff. It seems that these people are accorded additional social value when they had significant meaning to a greater number of people and their level of talent, position, circumstance, or other quality made them a greater surprise. Figure 3 is an abstract graphical representation of this proposition.

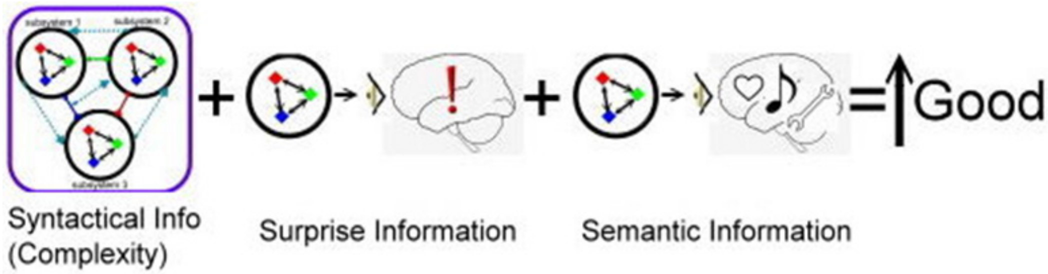

Figure 3. The box with the three interacting circles represents a syntactically deep complexity. The brain with an exclamation mark represents surprise, and the brain with a heart, musical note, and wrench represents semantics as perceived by an eye. The summation of different informational content can increase the value or good of an artifact or process.

When is a Complexity Net Positive?

C-I ethics is a consequentialist, utilitarian ethical theory. This genre of ethical theories weighs what ought to be done by aiming for actions that result in "the greatest good for the greatest number" as one well-known quip states. Jeremy Bentham and J. S. Mill, the pioneers of utilitarian ethics, proposed weighing several different parameters to help decide how to maximize a Good: the immediacy of the anticipated Good; how certain it is and whether it likely to recur; how many people would benefit and for how long; how intense the Good is; how much associated pain is anticipated; and for Mill, the quality of the Good. Universal ethics also recounts various options for the distribution of a Good among complexities, including whether an action should aim to distribute a Good equally to all complexities, to those with the least, to those with the most, some to each to maximize the total, and a Nashian model where the summed Goods are determined by multiplication (Vidal 2018). Developing a more fully realized calculus for maximizing the Good amongst complexities is beyond the scope of this paper, but suffice it to say that making a utilitarian calculus can be daunting in many cases. I will limit my discussion to some of the desiderata relevant to judging whether a complexity is net positive.

Note that artifacts and processes with deep informational content that are not complexities are not good or bad except in how they are utilized by higher complexities like humans. The Khmer Rouge flag or the "Little Boy" atomic bomb might come to symbolize an ideology associated with atrocities or a new weapon capable of massive destruction, respectively. However, these artifacts just sit incapable of being good or bad until utilized by a higher complexity capable of moral decision making.

Rather than recount evermore examples of complexities being net positive or net negative, we can broadly describe a few characteristics that would make a deep informational artifact or process ethically undesirable:

1. *Does the complexity intentionally or needlessly harm other deep informational artifacts/process directly or indirectly?* With a few notable exceptions exhibited by a few higher animals as noted earlier, it is complex people and groups of people who can project how their actions will affect other deep informational artifacts/processes and the future course of events. Our justice system and social mores recognize this fact and usually strive to limit or stop negative consequences to others, religious symbols, national flags, endangered animals, and other items highly valued by us and occasionally to higher animals—especially our pets.
2. *Lesser complexities that cause substantial harms to greater complexities*. Although we usually strive to avoid the extinction of higher animals, even those that cause us harm at times, like a poisonous snake, we do not share similar concerns about the loss or potential loss of much simpler complexities like mosquitos, smallpox, *Yersinia pestis* (the bacteria that causes the bubonic plague), and malaria. While even these simple organisms would be impossible to replicate with foreseeable technology, the misery that they impose on higher organisms, including humans, offsets any utilitarian calculus in their favor.

With further contemplation, C-I theory might reveal other broad rules for helping to determine when a deep informational artifact/process is not net-positive. Even with only these two caveats, it is often difficult to calculate reliably the best course of action a person should take in the complex landscape in which we exist.

It is a Complex World

C-I ethics, as with any other theory, will inevitably face shortcomings: no ethical theory is comprehensive in its ability to cover every contingency. Also, by having its precepts extended to include non-anthropocentric concerns, it often becomes more abstract in its application. The same problem occurs whenever you increase the sensitivity (so that you capture more cases or situations) of a medical test. You then lose specificity: you capture cases or situations that are not relevant. C-I theory would perhaps best find its stride by being a meta-theory—a theory that undergirds other theories that can be more easily applied in the field. Another important strength of C-I theory and others that incorporate complexity is that they recognize that the world is fundamentally (drumroll) . . . complex! Most traditional ethical theories, on the other hand, treat the world as though it is in some manner simple and that there is one primary variable that determines what is the Good, the best action to take, and so forth. In a more extended treatise, a complex-type ethical theory could more rigorously address some of the controversies that resonate in the field of ethics (and other philosophical areas as well). For example, accounting for the complexity of the world would

- Provide a new perspective on the issue of ethical relativism and subjectivism; i.e., there are fundamental reasons why it seems that ethics is relative to different times and cultures or why ethics seems to vary subjectively from person to person.
- Better explain why ethical theories founded on simpler precepts fail so frequently when applied to many real-world situations.
- Perhaps most boldly, complexity offers a possible basal explanation for how free will, which is needed for true ethics to be practiced by an agent, might be possible. Currently, many philosophers state that free will, despite its being apparent to us experientially, does not actually exist and that our choices are covertly deterministic a la Newtonian physics. Unfortunately, quantum mechanics, which is fully non-deterministic, is not a better answer for an underlying decision mechanism because it is fully random. Complexity science, however, has discovered several scenarios that are between a deterministic and indeterministic outcome—

and there might lie the substrate for a will that is free to make any of several choices. Ultimately, however, we should at least be agnostic regarding the final nature of apparent free will because we have much to learn about how the brain operates.

Complex-Information Theory Summary

Big historians need a broad ethical framework with which to examine better the ethics or morality of past events and especially events that might be looming in the "big future," such as human driven changes to the biosphere, artificial intelligence, transhumanism, and possible encounters with extraterrestrial life. Traditional ethical theories were primarily guided by human concerns, i.e., anthropocentric. A number of information-centric theories have been proposed in the past that broaden ethical concerns to that which is a complex system, various valuable artifacts, or at times even every thing that exists. C-I theory strives to broaden and refine these theories by beginning with a careful analysis of relevant laws or tenets from the second law of thermodynamics, information theory, and complexity science. Hopefully, by making the bridges from entropy to a careful analysis of information types and then to relevant complexity science, a solid theory can be constructed that has its foundation in the basic laws of physics but then can extend its grasp better to include all artifacts and processes worthy of ethical consideration.

Subsequently, others and I have identified complex systems as one important category of things that warrant our ethical consideration to the extent that to perpetuate and enhance them is ethically desirable—with some caveats. Clement Vidal and Jean-Paul Delahaye also identified various artificial human constructs as being complex systems and, therefore, worthy of preservation and promotion. However, if someone uses the usual criteria for identifying complexities, it quickly becomes apparent that many of their listed complexities such as works of art, microprocessors, and novels do not qualify as being such. Instead, C-I theory asserts that these and other items are valued for their deep semantical and surprise informational content. Furthermore, while complexities have intrinsic ethical value because ethics cannot exist without complex agents in a complex world, other types of informational content have instrumental value assigned to them by moral agents—in this case by humans.

Admittedly, C-I theory relies on abstractions that will often be difficult to apply in the field. It can still undergird more readily applied ethical theories and help to explain better the apparent limitations and contradictions that exist with traditional ethical theories. After all, as big historians well know, it is a complex world that is only becoming more complex as time unfolds.

Notes

1. As an aside for big historians, the "transistor" was first also developed and demonstrated at Bell Labs in December 1947 by physicists John Bardeen (1908-1991), William Shockley (1910-1989), and Walter Brattain (1902-1987). Hence, the "digital information age" arguably began at the very end of 1947 to 1948 at Bell Labs in Murray Hill, New Jersey (Riordan et al. 1999). Few, if any significant eras' origins can be pinpointed in location and time so precisely!

2. For a more thorough discussion about "information," please see my article, "The Unfolding of Information," (*JBH* 2:1). Please also note that there is an error on page 51, which states that the formula worked for only two equally likely messages—like the toss of a coin. Correctly stated, it measures any number of equally likely messages.

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