



Life's Complex Specified Information Is a Kind of Value

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In this article, we argue that complex specified information (CSI) is an important feature of life and a kind of value that all life instantiates. In support of our first thesis, we demonstrate that life's CSI operates at three interacting levels: cosmic fine-tuning for a life-supportive environment; genetic and epigenetic information within biological life; and the capacity of intelligent life to detect and create CSI. In support of our second thesis—that life's CSI is a type of value—we demonstrate that life's CSI shares traits (normativity, rarity, and gradedness) in common with the three classical values: epistemic, moral, and aesthetic. We suggest a value theory (axiology) research program guided by the hypothesis that value itself is best understood as (primarily) normative rarity. We show how this approach to axiology can be guided by perspectives derived from the integration of cosmology, biology, and information theory.



Justin Garson (2019, 1) observes that biological “functions are folded into philosophical debates about biological information.” In this article, we draw from scholarship on biological function to make progress in the philosophy of information and value theory. Our complex specified information (CSI) account of life’s informational foundation, including its functional component, will illuminate the nature and classification of values, so as to enrich value theory as a branch of philosophy.

Philosophers of biology overwhelmingly support “function talk in biology . . . and the normative connotations of this vocabulary” (García-Valdecasas and Deacon 2024, 21). So, for example, the function of the heart is to pump blood. When a heart’s blood-pumping capability is significantly reduced by disease, it is scientifically and medically respectable to say that the heart is *mal*functioning—deviating *badly* from a norm. The widespread support for this normative aspect of biological function persists despite continuing disagreement over exactly how to define biological function.

The organizational account of biological function¹—a younger rival to the selected effects account and the causal role account—seemed the best theory to account for the normativity of biological function. However, Luca Corti argues that the organizational account falls short of fully accomplishing this. Among the supplements that might improve the organizational account of life-functional normativity, Corti (2023, 20) recommends trying to “explicitly associate the notion of biological organization with the notion of value.” Corti’s call for a value analysis of function echoes earlier well-known acknowledgements that “function can’t be understood in a purely naturalistic/value-free way” (to quote one of our blind reviewers).² This article does this by arguing that life’s organizing CSI, which includes a normative (conditions of correctness) functional aspect, *is* a kind of value. In so doing, we offer a deeper explanation of the normativity of biological function. Our project emulates a recent trend of pluralist engagement with multiple theories of biological function.³ Although we offer a basic understanding of “function” (that is not limited to biological function) to develop our core thesis, we also selectively adopt insights from several theories of biological function to further articulate our account of life’s CSI.

Introduction to Complex Specified Information

Information is increasingly attracting the attention of scientists and philosophers (Floridi 2016). CSI is an account of information that deserves more attention than it has received because, unlike other meanings of information (e.g., Shannon information and Kolmogorov information), CSI contributes to a unified understanding of life’s functions—cosmic fine-tuning for the possibility of life, biological life, and intelligent life. Although Shannon, Kolmogorov, and other concepts of information relate to CSI in various illuminating ways (as we will discuss), none of them constitute a fundamental kind of value (we unpack

value here primarily as normative rarity) comparable to the three classical values (epistemic, moral, and aesthetic), as is the case with life's CSI.

We define CSI as a probabilistically complex (improbable) arrangement of entities that satisfies independently given specifications (tight constraints), such that it has function (i.e., function due to the joint occurrence of probabilistic complexity and tight constraints).⁴ "Tight constraints" specify a tiny region of possible entity configurations—the ones consistent with functional requirements—within the vast space of comparable conceivable possibilities. At many places in this article, we address multiple accounts of function, especially biological function. Our CSI definition focuses on function in the general sense of tightly structured capability within a probabilistically complex system,⁵ as illustrated and explained by examples to follow. This paragraph you are reading is a probabilistically complex arrangement of symbols (mainly alphabetic characters) that satisfies independently given specifications (including those of logic and grammar), such that it has a communicative function—a tightly structured capability (Hazen et al. 2007, 8576). Therefore, this paragraph is an instance of CSI (we call it "textual CSI"). Its communicative function is to define and exemplify CSI.

CSI is used here in an evaluative and axiological sense, not as a hypothesis about causal mechanisms. Accordingly, this article makes no claims about agency or origins and offers no critique of evolutionary mechanisms; its focus is exclusively on the normative and value-theoretic significance of life-functional information.

The term "complexity" in our CSI definition is used in the probabilistic sense standard in Fisherian analyses of stochastic processes: it measures the difficulty a stochastic process faces in generating a target configuration. This notion of complexity evaluates the adequacy of candidate mechanisms. It is importantly different from algorithmic or Kolmogorov complexity, which measures compressibility relative to a universal Turing machine. Algorithmic complexity evaluates description length not probability of formation via stochastic processes and is therefore complementary to—but not a replacement for—the probabilistic complexity central to CSI.⁶

The kind of rarity analyzed in this article is a consequence of the tight constraints consistent with functional requirements.⁷ The previous paragraph's particular communicative function is a rare capability because it is generated by adherence to tight constraints so as to distinguish it from (i) possible arrangements of alphabetic letters that communicate *different messages*, and (ii) the vastly larger number of ways to assemble gibberish so as to communicate *no meaningful messages*. Throughout this article, we mainly refer to rarity in reference to comparable conceivable possibilities (i.e., the space of possibilities) not actual frequencies in the world. Meaningful sequences of alphabetic characters are extremely rare in the space of possibilities, even though they are not rare in actual frequencies (due to Earth's billions of people).

An airplane embodies CSI because it is a technologically functional complex arrangement of parts that satisfies the independently given specifications (tight constraints) of ways to be an airborne transportation machine. The tight constraints of airplane CSI specify a tiny region of possible mechanical part configurations—the ones consistent with functional flying requirements. Such functional requirements specify a tiny region in possibility space by virtue of the conjunction of the physical laws of our cosmos (e.g., gravity), the nature of our planet's atmosphere, and many other factors. These constraining factors are independent of any specific airplane construction efforts exerted by any technologically capable species of life. These specifications (tight constraints) are independently given by a particular planetary–cosmic context. Such is the character of technological CSI.

Biological CSI makes possible the maintenance and reproduction of an organism (see the section “Biological CSI: Information that Guides the Maintenance and Reproduction of Life”). An organism embodies CSI because an organism perpetuates its own existence by means of hierarchically coordinated systems and subsystems, each of which is a biologically functional complex arrangement of parts that satisfies the independently given specifications (tight constraints) of ways to contribute to the state of being alive.⁸ The tight constraints of biological life's CSI specify a tiny region of possible part configurations—the ones consistent with biological life's functional requirements. Such functional requirements specify a tiny region of possibility space by virtue of the conjunction of physical laws (e.g., laws governing molecules), the traits of a local life-friendly environment, and other factors treated in the first two subsections of the section “CSI Is a Central Feature of Life.” These constraining factors are independent of (and temporally/explanatorily prior to) any specific events that produce biological organisms. These specifications (tight constraints) are independently given by a particular planetary–cosmic context.

Although technological and biological CSI exhibit qualitatively different kinds of function, they both share the common traits of CSI: probabilistic complexity and tightly constrained functional specificity. Textual CSI, described earlier, likewise exhibits these traits. Life's CSI—including biological, technological, and textual CSI—always possess function: transportive, reproductive, sensory, metabolic, communicative, logical, poetic, etc.

The functional component of life's CSI requires more explanation. In the case of textual CSI, consider a paragraph as a unit of discourse that expresses an idea by means of a sequence of alphabetic letters. What a unit of discourse does (a conceptual–communicative function) is inherent to what a unit of discourse is (a conceptual–communicative entity). This analysis helps support our thesis that function is a necessary aspect of life's CSI.

We can extend this argument to biology. A gene also contains sequence information: a sequence of bases within DNA—adenine, cytosine, guanine,

and thymine. Francis Crick (1958, 144) pioneered the recognition of such sequence information: “By information I mean the specification of the amino acid sequence of the protein.” DNA is unzipped to use this information: the sequence information of a gene codes for a corresponding sequence of amino acids that fold into a protein. This means that a gene is an instance of biological CSI because it is a probabilistically complex sequential arrangement of bases that satisfies the independently given specifications (tight constraints) of ways to code for a functional protein, such that it helps support life. The capability of a gene to help generate a functional protein is itself a function of that gene. So, function is an essential aspect of both the gene’s CSI and the corresponding protein’s CSI. Such biological CSI analysis—in conjunction with the earlier parallel technological and textual CSI analyses—cumulatively supports our thesis that function is inherent to all of life’s CSI.

Partial degradation of life’s CSI, such as heart disease, can result in various degrees of dysfunction (malfunction), but such dysfunction is quite different than a CSI-exhibiting entity never having had any function at all—completely functionless in life’s history. We amplify our CSI analysis of biological information and biological function in the sections “Biological CSI: Information that Guides the Maintenance and Reproduction of Life” and “The Rarity of Value: A Consequence of Small Selection within Vast Possibility Space.”

We should further explain the complexity of CSI. The complexity (C) of CSI is probabilistic (not descriptive or Kolmogorov)⁹ complexity. The greater the probabilistic complexity (e.g., the more possible number sequences to potentially open a lock), the smaller the probability of that object or event (e.g., unlocking a lock by arbitrarily attempted combinations). Accordingly, our definition of CSI indicates that probabilistic complexity amounts to improbability. Probabilistic complexity on its own does not constitute CSI. An instance of CSI also requires specification.

A specification in CSI designates certain outcomes in possibility space. For example, ponder the specified card combination called a royal flush. A royal flush earns a high score in a card game because it is tightly constrained by card trait parameters, which makes it special. Such tight specifications render the resulting card hand a rare occurrence in the game. Rarity is one of the traits of value, as we argue in the section “The Rarity of Value: A Consequence of Small Selection within Vast Possibility Space.” This supports our thesis that life’s CSI is a kind of value.

Our account of CSI unpacks the most common pre-theoretical use of the word “information.” Such ordinary language use amounts to the kind of information that undergirds functions (tightly structured capabilities within a probabilistically complex system). This sort of information does not correspond to Shannon information, Kolmogorov information, or several other theoretical accounts of information beyond CSI. People ordinarily recognize such

information by its function: data enables a computer to display a book and an assembly line robot to help make an automobile. What such information does (function) is inherent to what that information is.

The remainder of this article focuses on establishing how cosmic fine-tuning for life, biological life, and intelligent life all have functions (characterized as tightly structured capabilities within a probabilistically complex system). Such functions exist in virtue of possessing both probabilistic complexity and a match to a tightly constrained, independently given set of specifications. This account of life's CSI function in the general sense also well accounts for some basic features of biological function, especially its normativity (conditions of correctness), as shown in the sections "Biological CSI: Information that Guides the Maintenance and Reproduction of Life" and "The Normativity of Value: Proper Function."

CSI Is a Central Feature of Life

To help recognize life's CSI as a kind of value, we demonstrate that CSI is one of the central features of life at multiple interacting levels, beginning with cosmic fine-tuning for life.

Cosmological CSI: Fine-Tuned for Life

The laws, constants, and initial conditions of the cosmos conform to a special set of requirements (specifications) that make life possible in our universe. Of the indefinite number of mathematical forms physical laws might take, those in a life-permitting cosmos must have certain forms. Such laws include a long-range attractive force like gravity that drops off with distance so that stars and planets can form, a very short-range strong nuclear force to bind protons and neutrons together stably in each atomic nucleus, and an electromagnetic force that drops off with distance to hold electrons in orbit around each atomic nucleus and transmit light energy from a host star to its planets.

The constants that calibrate natural laws, such as the gravitational constant that determines the strength of gravity and the initial conditions of the universe, are also coordinated to permit life. Some aspects of the fine-tuning of gravity are relative to yet other physical parameters. For example, gravity is fine-tuned relative to the initial condition of the density of matter in the early universe and factors controlling the Big Bang's expansion rate. "Holding these other parameters constant," Robin Collins (2009) explains, "if the strength of gravity were smaller or larger by an estimated one part in 10^{60} of its current value, the universe would have either exploded too quickly for galaxies and stars to form, or collapsed back on itself too quickly" to support life.¹⁰ "The lesson here," says Collins (2009, sec. 2.3.2), "is that a single parameter, such as gravity, participates in several different fine-tunings relative to other parameters." Many scientists accept that the universe is fine-tuned for life in the way Collins summarizes. Making this point, Luke Barnes (2012, 7) cites work by an impressively wide range of cosmologists. "They differ, of course, on what conclusion we should draw from this fact," Barnes notes.

An early study of cosmic fine-tuning, launched by Harvard biochemist Lawrence Henderson, argued that the peculiar properties of water and carbon dioxide—and the underlying laws governing carbon, hydrogen, and oxygen—are well suited for the only kind of life that appeared to him physically feasible, namely, carbon-based life. Henderson (1913, 312) concluded that “the biologist may now rightly regard the universe in its very essence as biocentric.” By this he primarily meant that the chemistry of the cosmos is functionally aimed at the support of life. As a pioneer of biochemistry and its use in biology, he identified a collectively improbable (probabilistically complex) arrangement of coordinated chemical regularities that satisfies the independently given specifications (tight constraints) of life-permitting chemistry. This constituted the preliminary development of the idea of cosmic CSI. Even if, contrary to Henderson (and many astrobiologists today), alternatives to carbon-based life are plausible, this does not undermine Richard Dawkins’s (1986, 9) point: “[H]owever many ways there may be of being alive, it is certain that there are vastly more ways of being dead, or rather not alive.” In the section “The Rarity of Value: A Consequence of Small Selection within Vast Possibility Space,” we explore this rarity feature of life’s CSI as evidence of its status as informational value.

Earlier we defined CSI as a probabilistically complex (improbable) arrangement of entities that satisfies independently given specifications (tight constraints), such that it has function. In this definition, “function” was used in the general sense of tightly structured capability within a probabilistically complex system. The fine-tuning of our cosmos, which constitutes CSI, renders it functional because it has the tightly constrained capability of supporting the possibility of life. These tight constraints render our fine-tuned-for-life cosmos rare in relation to other possible universes, the vast majority of which are incompatible with life.

It is important to emphasize that the complexity relevant to cosmological CSI lies not in the algorithmic length of the laws themselves, which may be quite short, but in the extraordinarily small region of the space of possible laws, constant-values, and initial conditions that jointly satisfy the independently specified functional requirement of permitting complex life. Even an algorithmically simple law—like Newton’s or Coulomb’s inverse square laws—could be one point in a possibility space whose life-permitting region is vanishingly small. The probabilistic complexity of cosmological fine-tuning therefore concerns the scarcity of life-consistent parameter combinations, not the compressibility of physical equations.

Even so, one way to connect CSI with algorithmic information theory (AIT) is to let AIT contribute to the recognition of a legitimate specification rather than characterize complexity. In many cases, the simplicity and non-gerrymandered character of a specification can be better recognized when it can be given a short description within the relevant mathematical or physical language (e.g., “life-permitting cosmos” in the case of cosmological fine-tuning).

Such descriptions are algorithmically compressible even when the underlying microstate or parameter combination is highly complex. CSI can combine this AIT-bolstered treatment of specification with probabilistic complexity, assessing how difficult it is for stochastic processes to land within the life-permitting region defined by that specification. On this view, AIT (in many cases) can help explain how we recognize a non-ad hoc specification, while probabilistic CSI quantifies how hard it is to realize that tightly constrained specification by stochastic processes.

For the “cosmic fine-tuning as CSI” argument to succeed, one need not formulate it as a rigorous statistical inference. Similarly, the rock art at Altamira, Spain (depicting bison, etc.) clearly instantiates CSI, even though the probability of getting these images on rock by chance is not known with statistical rigor. However, in a step toward statistical rigor in fine-tuning argumentation, Jeffrey Koperski (2005) and Collins (2009) have proposed solutions to the normalizability problem that might have otherwise undermined demonstrating the improbability (complexity) of universal fine-tuned features. Barnes (2018) offers a Bayesian way to answer the normalizability objection. Regardless of how this debate in probability theory plays out, local fine-tuned features (our next topic) are immune to such universal fine-tuned worries. So, in many cases, cosmic fine-tuning for life is demonstrably probabilistically complex (improbable)—thus sufficiently establishing the “C” of CSI in such cases.

Cosmic fine-tuning, which includes the features reviewed here, exhibits CSI because the laws, constants, and initial conditions of the cosmos collectively constitute an improbable (probabilistically complex) arrangement of coordinated factors that satisfies the independently given specifications (tight constraints) of how to make a life-permitting cosmos¹¹ and has function in the sense of a tightly constrained capability: the capability of supporting life.

For a treatment of “functional information” suggestive of the functional status of cosmic fine-tuning, see Robert Hazen et al. (2007, 8574–75): “All complex systems alter their environments in one or more ways, which we refer to as functions.” They analyze the information that makes certain functions possible in alphabetic letter sequences, RNA aptamers (RNA structures that bind a target molecule), and the Avida computer program aimed at simulating evolving life forms. Their account of functional information is aimed at explaining complex emergent systems, in all of which “interactions among numerous components or ‘agents’ produce patterns or behaviors not obtainable by individual components” (Hazen et al. 2007, 8574). Such systems exist at “every scale of the physical universe,” which should reasonably include cosmic fine-tuning for life.

In addition to universal fine-tuning, local conditions must also meet certain requirements if a place is to be life-permitting. Since Guillermo Gonzalez, Donald Brownlee, and Peter Ward (2001) introduced the “galactic habitable zone” (GHZ), studies have largely confirmed this restricted life-friendly

zone within a galaxy. Many astronomy textbooks now discuss the GHZ and acknowledge that a planet too near or too distant from a galaxy's center would be uninhabitable owing to multiple factors.

The circumstellar habitable zone (CHZ), as defined since the 1950s, is a narrow ring around a host star where liquid water is sustainable on a planet's surface. The prerequisites for planet habitability are numerous, and the list is growing: "The traditional definition of the CHZ, based on the radiant energy from the host star, is outdated and should be replaced with a definition that also includes such considerations as planetary impact rate, orbital dynamical stability and episodic reductions in the size of the astrosphere . . . Habitability factors are often interconnected in a complex web, and some factors can have multiple distinct effects on the habitability of a planetary system" (Gonzalez 2014, 56).

Local habitability requirements (especially for complex life) include having a planet of the right size and composition (appropriately orbiting the right kind of host star), the right kind of atmosphere, a global magnetic field, plate tectonics, a large appropriately distant moon, proper spatial relations to neighboring (and at times migrating) giant planets (like Jupiter), and much more.¹² Habitable environmental rarity is further increased by the many well-timed events (e.g., planet migration) that are preconditions for obtaining and maintaining many of the items listed here. Such local fine-tuned features collectively constitute a probabilistically complex (improbable) arrangement of entities that satisfies the independently given specifications of how to make and sustain a local habitable environment (within a given universe that has life-permitting physical–chemical laws).

Biological Complex Specified Information: Information that Guides the Maintenance and Reproduction of Life

Our characterization of CSI as a central feature of biological life, the point we will now support, is not an attempt to define life. Attempts at defining biological life have proved useful in certain fields, but there is no consensus on a definition. To proceed as a discipline, origin of life studies have had to grapple with what "life" minimally is. Fittingly, the notion of biological CSI made an early, but incompletely developed, appearance in that field.

Leslie Orgel expressed what origin-of-life researchers (like himself) would need to explain—namely, the origin of biological specified complexity. He noted that, in contrast to most nonliving things,

living organisms are distinguished by their specified complexity. Crystals are usually taken as the prototypes of simple, well-specified structures, because they consist of a very large number of identical molecules packed together in a uniform way. Lumps of granite or random mixtures of polymers are examples of structures which are complex but not specified. Crystals such as granite fail to qualify as living because they lack complexity; mixtures of random polymers fail to qualify because they lack specificity. (Orgel 1973, 189)

Orgel thought the “idea of information” could make “more precise” this joint occurrence of complexity and specificity in organisms. He stressed how “sequence information” in DNA “can serve to distinguish the contents of living cells from random mixtures of organic polymers” (Orgel 1973, 190–91).

Bernd Rosslénbroich (2016, 290) notes that “information processes are essential in all life functions.” He concludes: “Basically all structures of the organism must contain embodied information, whether it comes from the genotype or not.” In support of one of our major theses, biophysicist Bernd Küppers (like Rosslénbroich) concludes that information is the central unifying feature of life: “The fact that all phenomena of life are based upon information and communication is indeed the principal characteristic of living matter. Without the perpetual exchange of information at all levels of organization, no functional order in the living organism could be sustained. The processes of life would implode into a jumble of chaos if they were not perpetually stabilized by information and communication” (Küppers 2010, 170).

There is a range of opinion about the status of biological information, as Peter Godfrey-Smith (2007, 104) observes:

Some have hailed the employment of informational concepts here as a crucial advance . . . Others have seen almost every biological application of informational concepts as a serious error, one that distorts our understanding and contributes to lingering genetic determinism . . . Most of the possible options between these extreme views have also been defended. These include various arguments that some, though not all, of the popular uses of informational concepts in biology are legitimate.

Godfrey-Smith also notes (2007, 106): “The more contentious question then becomes whether or not biology needs another, richer concept of information as well as Shannon’s concept. Information in this richer sense is sometimes called ‘semantic’ or ‘intentional’ information.” He gives reasons to accept this richer sense of information in certain domains of biology. CSI accounts for this richer sense of information.

Similarly, John Maynard Smith (2000, 215) argues: “It does seem that there are today, in the living world, only two systems capable of unlimited heredity, that is, of transmitting an indefinitely large number of different messages: these are the genetic system based on nucleic acids, and human language.” Both of these systems involve symbolic sequence signals that contingently (not by necessity, as Smith emphasized) produce the targeted consequences of those transmitted signals. Smith notes that epigenetic mechanisms also play an important developmental role, for example, the “positional information” provided by the head–tail orientated gradient of the bicoid protein in a *Drosophila* egg.

More epigenetic types of biological information have recently surfaced. Some “systems approaches” to biology have emphasized the ubiquitous operation of “different regulatory levels such as genetic, epigenetic, and posttranscriptional gene regulation” (Rajewsky et al. 2018, vi). Such bioinformatic discoveries include many forms of “positional information.” For example, the three-dimensional organization of the genome within the cell nucleus “has an essential role in controlling genome function during normal growth, cellular differentiation, and stress response, showing that, overall, 3D reorganisation is tightly linked to changes in gene expression” (Fahmi, Sewitz, and Lipkow 2018, 1).

Philosophical reflection on systems biology has renewed efforts to understand what life is. Central to this ontological project is the systems biology study of “gene regulatory networks, rather than static DNA sequences as ‘codes,’” which “entails a different epistemology and ontology focused on the dynamic [informational] regulation of biological systems” (Green 2017, 5). Scholars also debate “whether systems biology explanations are mechanistic or not” (Green 2017, 5). This is understandable partly because systems biology increasingly relies on concepts like noise, filters, and amplifiers—which are derived from information theory and engineering (further supporting our CSI analysis of life).

Many biosemiotic practitioners have emphasized the importance of information theory to make sense of biological function. Wim Beekman and Henk Jochemsen (2023, 446) argue: “Biological regularity in protein biosynthesis appears dependent on *normative symbolic information processing*.” They think such biological information processing includes DNA as a carrier of “biological meaningful information.” Such biological information is “meaningful in the sense it delivers (eventually after some post-translational modification) a functional protein to a living cell. DNA contains functional information precisely in the context of the system of the living cell” (Beekman and Jochemsen 2023, 448). This approach contains some of the main features of our CSI account of biological information: CSI’s functionality (instructions for tightly structured capability within a probabilistically complex system) and normativity (maintaining conditions for correctness within an organism).

Cultural Complex Specified Information: Signs of Intelligent Life

Recall Smith’s (2000) reference to the “two systems” (human language and the genetic–epigenetic system) capable of “transmitting an indefinitely large number of different messages.” Intelligent life is capable of generating CSI, which we call cultural CSI. Language plays a prominent role in the conception, instantiation, and transmission of cultural entities. Technological CSI includes robotic programs that direct automobile assembly. The owner’s manual (textual CSI) for an automobile includes a specifications section that documents the right sort of oil and other fluids one should use.

Such cultural artifacts embody CSI. We noted earlier how an airplane embodies CSI because it is a technologically functional complex arrangement of parts that satisfies the independently given specifications (tight constraints) of ways to be an airborne transportation machine. So, cultural CSI includes the prominent subcategories of technological CSI and textual CSI. All forms of cultural CSI share (with cosmic fine-tuned CSI and biological CSI) the common traits of probabilistic complexity and tightly constrained functional specificity.

Altogether: Life's Complex Specified Information Operates at Three Interacting Levels

Life's CSI, we have demonstrated, resides at three interacting levels: cosmic fine-tuning for a life-supportive environment, genetic–epigenetic information within organismic life, and the capacity of intelligent life to detect and create CSI. At the middle of these three tiers, biological life itself is only possible if it resides within and properly interacts with a fine-tuned environment. At the top tier of life, intelligent life, CSI figures into the picture in a yet additional unifying manner. Culture, in at least the case of humanity, includes impressive achievements in creative literature, technology, and science—all of which involve CSI. So, we have demonstrated that all three levels of life's CSI interact with each other in ways that support an integrated theoretical framework for understanding life and its cosmic preconditions.

The relationship between the notions we have been employing can now be stated succinctly. AIT measures descriptive compressibility; Shannon theory measures uncertainty; CSI measures functional organization under probabilistic constraints. Because cosmological fine-tuning, biological regulation, and cultural artifacts all involve tightly specified functional requirements that must be met despite vast spaces of alternative possibilities, probabilistic complexity is their appropriate evaluative metric. CSI therefore captures the cross-domain unifying structure linking cosmological, biological, and cultural information.

Now we are ready to argue that life's CSI is a kind of value, which is a new theory of significance for the foundations of value theory and for how to account for key aspects of biological function.

Why Life-Functional Complex Specified Information Is a Kind of Value: Normativity, Rarity, and Gradedness

Philosophers traditionally have recognized three major kinds of value: epistemic, moral, and aesthetic (Tappolet and Rossi 2016). Normativity (conditions of correctness), or “oughtness,” is the most studied characteristic of these kinds of value. “Epistemic ought” means that a person should form and retain beliefs that are justified (e.g., avoid logical fallacies that violate conditions of correct reasoning), which in turn gives the person the best opportunity to arrive at truth. “Moral ought” means that persons should be (and do) good rather than

evil (ethically correct rather than ethically wrong). “Aesthetic ought” means that a person should appropriately recognize, enjoy, cultivate, and embody beauty. Although aesthetic value is more difficult to precisely characterize in comparison to the previous two classical values, we seem to often recognize it clearly.

People generally have strong intuitions supportive of this trilogy of assertions. Indeed, most people admire those who exhibit these values. The world ought to contain such virtuous persons, so the intuition goes. Disagreement over how exactly to understand these three kinds of value and their normative dimension leaves the intuition of this threefold normativity undefeated for most people. We propose a fourth major kind of value, life-functional informational value (understood as life’s CSI), which shares the common trait of normativity (and more) with the three classical values.

One might mistakenly think CSI has value only because biological life possesses it. Our account reverses this order of explanation. Biological life is valuable (or partly so) because it instantiates CSI—an intrinsically normative structure consisting of tightly constrained functional organization that defines proper functioning. CSI is therefore not a proxy for biological life’s value; it is the ground (or the partial ground) of that value. This distinction clarifies why CSI belongs alongside the classical values rather than merely being completely parasitic on them.¹³

The Normativity of Value: Proper Function

The value trait of normativity means that entities ought to function properly (satisfy conditions of correctness). Persons ought to function in a proper manner epistemically, morally, and aesthetically. We rehearsed this in the previous two paragraphs. An account of normativity as proper function across the three classical values helps us identify life’s CSI as a kind of value because life’s CSI too exhibits this trait characterized in this way.

Normativity as Proper Function

Does our universe, which many argue has been “selected” from a multiverse or from possibility space (Vidal 2010), have proper functions (preeminently, its capability to support life)? Several selectionist accounts of proper function pioneered by philosophers of biology and philosophers of technology (Krohs and Kroes 2009) motivate an affirmative answer. Some organizational accounts of ecological function also support our treatment of cosmic CSI. For example, Nei Nunes-Neto et al. (2014, 123) define “function in ecology as a precise effect of a given constraint on the ecosystem flow of matter and energy performed by a given item of biodiversity, within a closure of constraints.” Ecological function exists on a higher level than function within individual organisms. Consequently, an ecological approach to biological function exhibits some traits that have much in common with the highest level (scale) of analysis

in the natural sciences, which is in cosmology. Cosmological functions that contribute to life-permitting capabilities operate within an ascending hierarchy of subsystems contained within yet higher systems. The three levels of life's CSI (cosmic, biological, and intelligent) all properly function in the most robust sense when all three are in place and interact in the manner we have described.

Erik Weber and his colleagues offer an analysis of technological and biological function that supports our thesis. They explain the “epistemic value of biological and technical (advantage) function ascriptions in terms of the idea that their underlying structure provides the means to answer what-would-happen-if questions” (Weber et al. 2019, 560). In one biological function case study, the white underparts of seagulls were hypothesized to have the functional advantage of rendering the seagulls inconspicuous to their aquatic prey against a bright sky. After being artificially dyed black underneath, seagulls were shown to be less able to capture prey, thus answering a what-would-happen-if question. This what-would-happen-if investigative approach regarding biological function also helps make sense of cosmic fine-tuning for life as CSI. This is so because what-would-happen-if analysis shows that there are vastly more ways for a cosmos to be life-prohibiting (nonfunctional with regard to the possibility of life) rather than possess life-permitting functions. Although cosmologists have much less interventionist control (for the purpose of what-would-happen-if analysis) over their subject matter than biologists (e.g., artificially blackening the bellies of seagulls), a similar functional advantage analysis is useful.

To better grasp life-functional CSI's normativity, let us ponder the widely held intuition that things ought to function properly as specified by their own internal (especially informational) parameters for what counts as flourishing. We take it that when organismal parts or artifacts function properly, they function in a particular way. The proper function of the heart is to pump blood. The proper function of a watch is to tell time.

Wayne Christensen (2012, 104–6), while aiming to naturalize functional normativity in biology, notes the “deeper and thornier issues” associated with locating the “basic source of normativity.” In contemplating the “proper function of a heart,” he notes that some have supposed that it has “to do what ancestor hearts did that made them the target of selection” (this is a “selected effects” account of function; Christensen 2012, 105). However, “identifying this putative proper function will not allow us to conclude that this heart now ought to do what it's [sic] ancestor hearts did, or that it is bad if it does not” (Christensen 2012, 105). Christensen (2012, 104–6) proposes an alternative way to naturalize normativity that is roughly equivalent to the organizational account of biological function, which we partially appropriated earlier: “Here I present an account that identifies a basic form of valuational normativity in autonomous systems.” Some systems (e.g., living organisms) have “a very special relationship between their organization and their existence because (unlike rocks) they actively construct the conditions which give them unity and

ongoing persistence” (Christensen 2012, 104–6). He explains further: “A system is autonomous if it tends to generate the conditions for its persistence, and if it has infrastructure that contributes to this self-maintenance. Infrastructure here refers to persistent, relatively stable structure that shapes more dynamic system-maintaining processes, with the cell membrane of living cells being a paradigm example.” (Christensen 2012, 106).

Biological Proper Function Rooted in Genetic and Epigenetic Complex Specified Information

Our argument for the normativity of life-functional CSI is supported by recent discussion of biological information. For example, Nicholas Shea (2011, 183; emphasis added) notes that Kim Sterelny and Maynard Smith (see section the “Biological CSI: Information that Guides the Maintenance and Reproduction of Life”) “were the first to argue that genetic information should be understood in terms of teleofunctions, leading to a sense in which genes carry semantic information, with *conditions of correctness* or satisfaction.” This research supports our thesis that life-functional CSI in biology is characterized by normativity (conditions of correctness). Teleofunctions are the natural functional goals of organismal parts, which are coded for by biological information. This information-mediated process enables the perpetuation of life by particular functional means, such as limbs for walking. Environmental factors (e.g., toxins) can frustrate reaching such natural functional goals. In response to critiques of this view of biological information, Shea (2011, 187) argues that DNA carries “semantic information about something other than its own sequence properties” and that “there really are consumers of the message carried by DNA.” He concludes that there is a strong case for the “existence of substantive genetic information” (he similarly recognizes epigenetic information; Shea 2011, 189). Indeed, biological information is about producing teleofunctions (proper functions) that might or might not be correctly satisfied. This supports the case for the normativity of life-functional CSI.

The normativity (conditions of correctness) of biological information is also supported by numerous error-dampening and error-correction capabilities within organisms. The genetic code has built-in features that mitigate the effects of errors. For example, if a single DNA base pair is accidentally lost within an open reading frame section of DNA that is supposed to code for a protein, a minus-one frame shift error (mutation) occurs that would (without error-dampening capability) cause the cell to produce many copies of a broken or toxic protein. Fortunately, the DNA code system has three stop codons (TGA, TAA, and TAG) that often are triggered by such minus-one frame shift errors, enabling the cell to resist making harmful or resource-wasting broken proteins. David J. D’Onofrio et al. (2012, 9) have identified this error-dampening genetic logic as a “grammatical rule” that produces “halt commands” if a frame-shift mutation (FSM) occurs. They further note: “Less obvious is the fact that

potential stop codons present during a FSM, are not seen in genes that exhibit no frame shift mutations. They are inconspicuous within the normal context of gene expression and yet become viable during erroneous FSM expressions without prematurely terminating non FSM codonic regions. This shows that the genetic code, in part, is constructed to lessen the impact of frameshift errors due to the strategic use of grammatical rules” (D’Onofrio et al. 2012, 9).

Such error-correction procedures are part of the cell’s information-processing system at multiple junctures, including the repair of DNA replication errors, and fixing transcription and translation errors as DNA’s code is used to arrange amino acids into proteins. These facts about the self-regulating and self-perpetuating character of the information-processing systems of living organisms suggests an intrinsic oughtness to life and its underlying CSI.

Sune Holm’s philosophy of disease recognizes the normativity of life’s functions regardless of the events that led to their origin. He explains disease in terms of an organizational account of function according to which “the function of organismic parts and processes is conferred on them by their current role in the self-maintaining organization of the organism. I suggest that the dysfunction requirement [for defining disease] should be stated in terms of the organizational account of normative function in order for it to provide an adequate characterization of the problem cases discussed” (Holm 2014, 330).

He approvingly points to how “proponents of the organizational approach begin by pointing out that it is by virtue of being self-maintaining systems that organisms realize ‘the relevant causal regime in which the teleological and normative dimensions of functions can be adequately naturalized’” (Holm, 2014, 338). Our pluralist posture toward biological function allows us to appropriate insights from multiple perspectives on biological function, which collectively support the normative dimension of biological function. This trajectory helps establish biological CSI as a kind of value (normative rarity).

Similar to Holm, Jason Winning (2020) offers an account of proper function and natural norms in biology. He does so by analyzing performance-monitoring and censoring mechanisms at the subcellular level. For example, when sensor proteins detect too many malfunctioning (unfolded or misfolded) proteins, signals are sent to the cell nucleus to mitigate this error, such as by the production of more chaperone molecules that assist in proper protein folding. Such error-detection signals might also prevent the cell from undergoing cell division to prevent further proliferation of such malfunction. In severe cases, error-detection signals can trigger the release of enzymes called caspases that cause particular cells to self-terminate. Winning (2020, 16) concludes:

These examples have several features in common. In each case, there is some situation indicative of performance which is either registered as present or not present . . . triggering an unequivocal all-or-nothing type of response . . . In

other words, the recognition and typing of a performance token, an implicit if-then mapping from this recognized performance type to a categorical censuring response, and the context-dependent execution of that response, all the ingredients needed . . . to realize norms of performance based on censorious acceptance and rejection. Since what is being categorized is the performance of some subsystem or component, each of these processes can ground a distinction between functioning and malfunctioning for that subsystem/component.

He further argues that such subsystem informational normativity processes “can collectively realize a higher-level, and more complex, standard of functioning—not due to the fact that the higher-level censuring is causally dependent on the low-level censuring, but because it is *constituted* by it” (Winning 2020, 17). On this basis, he argues for an internal organismic perspectivalism that constitutes a “fully naturalistic, mind-independent grounding of proper function and natural norms” (Winning 2020, 1). So, “what counts as the proper function of a biological subsystem or trait is a matter of the perspective that the biological system, itself, has on what counts as proper functioning for that subsystem” (Winning 2020, 19). This nonconscious perspectivalism, though in need of more justification and articulation, constitutes a kind of biological normativity that is deeper than mere instrumental means–ends coherence.

José Pérez-Escobar (2024, 26–27) has developed a descriptive logical account of such teleological “proper function” reasoning that undergirds much of biological science. His “minimal logical teleology” makes sense of the commonalities and epistemic bridges between the study of biology and human artifacts, while also noting their main difference: “[A]rtifacts and biological phenomena feature extrinsic and intrinsic purposiveness respectively” (Pérez-Escobar 2024, 27). Nevertheless, these two domains of study share the same basic teleological explanatory structure: “The logical structure features an item that yields consequences, which are in turn evaluated relative to a purpose” (Pérez-Escobar 2024, 26). This teleological logic helps make sense of the internal organismic maintenance of proper function Winning analyzes (e.g., sensor proteins that detect misfolded proteins and send signals to mitigate this deviation from normality). A teleological explanation recognizes that a “purpose” makes sense of an item so as to create expectations of that item: “It should exist, it should have certain characteristics, it is normatively charged inasmuch as it should ‘work’ in a certain way or else it is dysfunctional” (Pérez-Escobar 2024, 27).

Pérez-Escobar shows the utility of his minimal logical teleological account by demonstrating how it makes sense of the discovery of a directionality or “compass” system that helps many organisms navigate back to their nest location (and more). “The remarkable observation that the firing activity of some neurons correlate with an animal’s angular facing direction promoted a compass analogy

and the belief that these cells provide a cognitive representation of angular direction” (Pérez-Escobar 2024, 33). Teleology guided the discovery of this and other components of various biological GPS systems in the animal kingdom. The biological–artifact comparison did its work by means of a minimal notion of teleology regarding organismic function. Pérez-Escobar’s analysis of this operation in scientific practice does not require commitment to any particular theory of biological function. His case study of the discovery of “compass” systems in animals illustrates how, regardless of how one conceptualizes biological function, “ascribing a role/function/purpose . . . to biological phenomena is typical in” biological research (Pérez-Escobar 2024, 33).

This article uses Pérez-Escobar’s minimalist operational approach to find some common ground among competing accounts of biological function. We use these common insights to argue for normativity in biological function, which, in turn, supports our thesis that life’s CSI is a kind of value (normative rarity).

Is Informational Normativity More Fundamental Than Other Kinds of Normativity?

There is evidence that life-functional informational normativity is more fundamental than moral, epistemic, and aesthetic normativity. This section further supports our argument that life’s CSI is an important kind of value. We begin with moral normativity.

Life-functional informational normativity sometimes is explanatorily prior to moral norms. Gluttony violates the CSI functional normativity inherent to healthy living. Overeating and the resultant litany of weight-related illnesses partially inhibit humans from functioning properly. The specifications for proper function possess an informational oughtness that produces health problems when violated. Informational normativity means that human bodies possess particular features (made possible by CSI) that suit them for certain functions and not for others. Improper use leads to partial dysfunction—degradation of some of the CSI embedded in this anatomy and physiology. Here we see how informational normativity provides some of the foundation for moral normativity within human behavior with respect to diet. Examples could be multiplied with respect to exercise, sleep, substance abuse, and more.

Moreover, a similar connection holds *mutatis mutandis* between informational normativity and epistemic and aesthetic normativity. For example, scientific realists argue that in the case of our most theoretically virtuous (evidentially accurate, fruitful, etc.) scientific ideas, the core statements of such theories approximately grab hold of reality. Note that such core theoretical statements, which carry epistemic value, constitute textual CSI—scientific literature constructed from natural human language and special scientific–mathematical symbols. This is one sense in which informational value is more fundamental

than epistemic value. This line of reasoning suggests that informational value is more fundamental than the classical values in certain respects. That is, even if the values of rationality, goodness, and beauty are fundamental with respect to their own domain, they are not absolutely fundamental, at least in some respects. They are grounded (to some extent) in something else—namely, life's informational value.

Life-functional informational normativity is sometimes explanatorily prior to aesthetic norms. Environmental pollution often violates the CSI functional normativity inherent to healthy ecosystems. The aesthetic value of these environments is thereby degraded. In the absence of pollution, biological CSI more thoroughly guides the flourishing of flora and fauna, with the resulting instantiation of more aesthetic ecosystem properties. The aesthetic traits of the literary arts, such as novels and poems, supervene on the textual CSI of which they are composed. Although artistic license allows for some departure from the constraints of more ordinary language use (customary vocabulary, grammar, etc.), a pervasive or complete breakdown of such conditions of correctness results in gibberish—not literary art.

We again recognize the fundamentality of informational value when considering the nature of communication and the transference of values from one to another. Many people of diverse worldviews think that properly functioning persons will exhibit the three classical values (that is, be informed by rationality, morality, and aesthetic sensibility) and communicate such value (that is, inform or transmit form) to others. Informational–communicative transactions among persons and among organisms/things in the world may themselves exhibit one or more of the three classical values in varying degrees. For example, Shakespeare's *King Lear* is more aesthetically valuable than the gibberish of the town fool, Plato's *Republic* contains more epistemic value than the rants of the hoi polloi, and kind words exhibit moral goodness in a way that harsh words do not. Persons inform one another (communicate) intentionally in ways that involve all three classical values.

Notice how we use informational terminology (e.g., “inform” and “transmit form” and “communicate”) to help illuminate the three classical values. This suggests that at least in some respects, informational value is more fundamental than the three classical values.

Some recent efforts to understand normativity in a “liberal naturalism” manner resonate with our thesis.¹⁴ Consider, for example, Evan Fales's (2012) case for naturalistic moral realism. He attempts to ground all ethical normativity in natural teleologically ordered systems (paradigmatically in living organisms) in a way that resembles our case for informational normativity. While we argue that informational normativity is sometimes explanatorily prior to moral normativity, Fales attempts a complete reduction of moral normativity to informational normativity (without calling it such).

The Rarity of Value: A Consequence of Small Selection within Vast Possibility Space

Rarity is another common trait that life's CSI shares with epistemic, moral, and aesthetic value. We argue that there are few ways to be reasonable, moral, beautiful, and alive—that is, in comparison to the many more ways to be unreasonable, evil, ugly, and dead (lacking sufficient life-functional CSI).

Rarity was staring us in the face in our earlier exploration of cosmic fine-tuning for life as well as the genetic and epigenetic information that makes possible the maintenance and reproduction of organisms. Remember that if the strength of gravity were smaller or larger by an estimated one part in 10^{60} of its current value, the universe would have either quickly collapsed back on itself or expanded too rapidly for stars to form. In either case, such a cosmos could contain no life. Even within our fine-tuned cosmos, local conditions must meet many additional criteria to be habitable.

The extreme rarity of cosmological fine-tuning is echoed in molecular biology. Douglas Axe's (2004) experimental work implies that "the overall prevalence of [amino acid] sequences performing a specific function by any domain-sized fold may be as low as 1 in 10^{77} , adding to the body of evidence that functional folds require highly extraordinary sequences." A fold within a particular protein is an independent structural unit of that protein. Other studies have reinforced Axe's conclusion.¹⁵ These studies collectively demonstrate empirically that the percentage of life-friendly amino acid sequences (ones that make useful proteins) out of the total possible sequences is extremely rare. Recall Dawkins's (1986, 9) way of expressing this: "[H]owever many ways there may be of being alive, it is certain that there are vastly more ways of being dead, or rather not alive."

Epistemic value also exhibits the trait of rarity. Given that there are many possibly ways for beliefs or our belief-forming mechanisms to go wrong, knowledge is rare when compared to all the possible ways a person could hold unwarranted beliefs. Analysis of theoretical virtues also points to the rarity of epistemic value. Theoretical virtues are the traits of a theory that show it warrants acceptance. Such virtues include evidential accuracy, explanatory depth, and fruitfulness (Keas 2018). Although the characterization and epistemic status of the theoretical virtues are contested, many scholars affirm that these virtues help us infer which rival theory is the best explanation. Studies of prominent theories, especially in the natural sciences, have helped us recognize just how rare virtuous theories are compared to the vast number of possible ideas that would (rightly) be judged theoretically less virtuous (e.g., theories that are evidentially inaccurate, explanatorily shallow, fruitless, and ad hoc).

Similar considerations hold for aesthetic and moral value. Beauty requires a kind of harmony and order (among musical notes, words on a page, or pastels on a canvas) that is rare compared to the vast number of possibilities for

disharmony and disunity. This point holds even if, as many have argued, our universe contains much beauty. With respect to possibility space, such beauty is rare and unexpected. The frequency of beauty (or any other classical value) in the actual world is not at the heart of our argument. Rather, we have focused on rarity as a consequence of tight constraint gauged in reference to comparable conceivable possibilities (i.e., the space of possibilities), not actual frequencies in the world.

For example, consider some of the aesthetic traits of a good story. A good story will exhibit beautiful traits such as wittiness, irony, simplicity, and unity. There are many more ways to write stories that score low (rather than high) in such aesthetic traits. The last two aesthetic qualities deserve special attention in this regard. Simplicity refers to a story that is not more complicated than what is needed to fully develop the plot. There are far more ways to gratuitously complicate a story than to tell a story with graceful simplicity. How about the trait of unity (or unification)? A story will exhibit a pleasing unity if it illuminates very different kinds of human experience by showing how these experiential components belong to a larger whole. There are many more ways for a story to exhibit disunity rather than unity. It takes more effort and more artistic skill to craft a story with high degrees of these aesthetic properties.

There is a similar principle of moral rarity. Highly exemplary moral people are rare, and it is for this reason that we honor and seek to emulate such persons. Part of the reason for the rarity of highly moral people is that for any given highly prized moral act in a certain circumstance, there are a vast number of ways to act that would fall short of the moral ideal. For example, consider the highly prized moral action of assisting a stranger in a way that best matches the stranger's short-range and long-range needs, and that does so within the domain of the helper's capabilities at that time (with due consideration for appropriately maintaining financial resources for helping other people in the future, etc.). There are a vast number of ways to act in this situation that would fall short (to one degree or another) of the moral ideal. For example, you could do less than what you are capable of doing, or you could act without the appropriate amount of effort to become acquainted with the precise nature of the stranger's needs, and so on. The moral ideal occupies a tiny region within the space of such possibilities for action and motivation in that situation.

Let us probe deeper into the motivational reasons for the rarity of highly moral acts. Even in cases where someone acts publicly in an ostensibly moral manner, research shows that very frequently, the motivation for such acts is selfish (or a mixture of selfish and unselfish motives). For example, "the most investigated form of moral hypocrisy is *pragmatic* hypocrisy in which people fake moral commitment for their own advantage" (Lindenberg et al. 2018, 393). Furthermore, there is "a different form of hypocrisy in which people

take a moral stance with regard to norms they endorse without thereby also expressing a commitment to act morally. Rather they do it in order to feel good” (Lindenberg et al., 2018, 393). This is hedonic moral hypocrisy. The rarity principle of morality is widely acknowledged among scholars.

The Gradedness of Value: Weighing Worth on a Scale

Philosophers have long recognized that value comes in degrees, including different grades of epistemic, moral, and aesthetic value. On the epistemic scale of value, persons form beliefs with varying degrees of justification (some beliefs are more rational to hold than others) and hold beliefs with varying degrees of confidence or credence. On the moral scale of value, persons embody different levels of goodness (and evil), and various actions can be more or less praiseworthy or blameworthy. On the aesthetic scale of value, persons, things, and events embody or instantiate various degrees of beauty, from aesthetic excellence (e.g., sublimity and sophisticated elegance) to mundane aesthetic goodness (e.g., cuteness and neatness). For example, a very low degree of neatness might be barely above the threshold of junky clutter. Regarding epistemic, moral, and aesthetic value, it is difficult to precisely quantify degrees of value, although we generally think our comparative value judgments reliable.

By contrast, life’s CSI is not only graded but is often more readily quantifiable. The amount of CSI present in a given case sometimes can be determined by a precise calculation. For example, the amount of information encoded in DNA can be measured in bits.

Conclusion

CSI is a probabilistically complex (improbable) arrangement of entities that satisfies independently given specifications (tight constraints), such that it has function (i.e., function due to the joint occurrence of probabilistic complexity and specification). CSI, including its functional component, stands out as rare and special as a consequence of being tightly constrained. These narrow constraints distinguish any instance of CSI from the vast number of comparable conceivable possibilities—configurations that lack tightly structured complex system capability (“function” in the most general sense). Life’s CSI entails function (so defined) that operates within intelligent life, biological life, and their cosmic preconditions. The fine-tuning of our cosmos, which constitutes cosmological CSI, means that our cosmos is functional in the sense that it has the very interesting and tightly constrained capability of supporting biological life and intelligent life.

Biological CSI is functional in a sense that is more nuanced than the function of cosmic CSI. There is still much work to be done to potentially settle how to thoroughly account for biological function. However, despite this longstanding inconclusive debate, philosophers of biology overwhelmingly recognize the

legitimacy of function talk in biology, and the normative connotations of this vocabulary. Biological CSI, with its functional component, makes deep sense of biological function, especially when such CSI is understood as a kind of value—characterized preeminently as normative rarity. We especially support this conclusion by arguing for—not merely assuming—the normativity of biological function. CSI is an intrinsically normative informational structure that makes an organism possible. CSI is the bearer of functional normativity (proper function), the locus of the constraint-guided functions that collectively distinguish organisms from nonliving material objects. CSI is therefore not a proxy for biological life's value; it is the ground (or the partial ground) of that value. This distinction clarifies why CSI belongs alongside the classical values rather than merely being completely parasitic on them.

We explored how CSI is one of the most important unifying features of life. The support for this thesis consisted of demonstrating how life's CSI resides at three interacting levels: cosmic fine-tuning for a life supportive environment, genetic-epigenetic information that makes possible the maintenance and reproduction of organisms, and the capacity of intelligent life to detect and create CSI—including textual and technological CSI.

We then argued that this three-tiered life-functional CSI is a kind of value because, along with the three classical values (epistemic, moral, and aesthetic), it shares the properties of normativity (oughtness or proper function), rarity (a consequence of being a tightly constrained subset of comparable conceivable possibilities), and gradedness. We allocated the most space for demonstrating the normativity of life's CSI. That is our strongest argument for the conclusion that life-functional CSI is a kind of value.

Our article's principal contribution is this: we have demonstrated how CSI is a distinct kind of value characterized by normative rarity. Secondary or supportive corollaries include: CSI unifies the cosmological, biological, and cultural domains of functional information; CSI grounds functional normativity; and CSI is explanatorily prior (in limited respects) to the classical values—epistemic, moral and aesthetic.

Our CSI account of information, including its normative functional component, illuminates the nature and classification of values, which enriches axiology (value theory) as a branch of philosophy. This exploration of some of the surprising relationships between “is” and “ought” highlights ways in which axiology is entangled with philosophy's other major branches: metaphysics and epistemology.

While classical axiology has focused on normativity and gradedness, the common value trait of rarity has received less attention. We argue (memorably) that there are few ways to be reasonable, moral, beautiful, and alive but many ways to be unreasonable, evil, ugly, and dead (lacking sufficient life-functional CSI). Our study of life-functional informational value (CSI) might help others

better explain the property of rarity in epistemic, moral, and aesthetic value. We offer this insight as part of a research program in axiology, which also might provoke a better articulation of other kinds of value beyond the ones discussed in this article. Central to this suggested axiological research program is the hypothesis that value itself is best understood as (primarily) normative rarity (rare oughtness among conceivable possibilities). We have demonstrated how this approach to axiology can be guided by perspectives derived from the integration of cosmology, biology, and information theory.

Similarly, we encourage the investigation of further ways in which life's CSI is a more fundamental kind of value than the three classical values—epistemic, moral, and aesthetic. This approach has already strengthened our thesis that CSI is a type of value. Axiology might become more fruitful by the discovery of yet additional ways to integratively study the classical values with the assistance of a proper functional CSI account of life. Moreover, conclusions regarding CSI as a kind of value will have wide-ranging implications for long-standing debates in metaphysics, philosophy of mind, philosophy of nature, and philosophy of technology. Clarifying the nature and role of informational value, given its centrality to life and current renewed interest in information in our technological age, is of particularly relevant and timely interest. Regardless, there are many good reasons to now conclude that life's CSI is a kind of value.

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Competing Interests

The authors declare that they have no competing interests.

Notes

- ¹ Matteo Mossio, Cristian Saborido, and Alvaro Moreno (2009, 813) define “biological functions as causal relations subject to closure in living systems, interpreted as the most typical example of organizationally closed and differentiated self-maintaining systems. We argue that this account . . . provides an explanation for the existence of the function bearer and, at the same time, identifies in a non-arbitrary way the norms that functions are supposed to obey.”
- ² Although it is debatable whether such earlier studies of function imply a repudiation of naturalism (as possibly implied by the reviewer), we thank this reviewer for directing us to the following value-analytic approaches to function, which support our thesis: Peter McLaughlin (2000), Parisa Moosavi (2019), and Mark Bedau (1992). McLaughlin (2000, 5) notes that “[a]s it stands, the assertion that natural functions are either metaphorical or divine is simply one particular variant of an antinaturalistic credo and is prima facie no less metaphysical than a commitment to intrinsic value in nature.” Moosavi uses an organizational account of biological function to “argue that the flourishing-based concept of function that forms the basis of the neo-Aristotelian account of natural goodness is explanatorily indispensable to biology, and therefore essential to the understanding of living things” (quotation of the essay’s abstract), and she approvingly cites how “Bedau (1992) and McLaughlin (2001) have defended a *value-based* approach to understanding functions” (Moosavi 2019, 10). She also argues that “the explanatory role of organizational function ascriptions in biology can support the neo-Aristotelian concept of function, without implying that biology can give us a substantive account of moral virtue” (Moosavi 2019, 2). Finally, Moosavi (2019, 17) concludes that “organizational function ascriptions presuppose a notion of doing well for the organism that accords with the neo-Aristotelian concept of flourishing and flourishing-based evaluation. Thus, there is an evaluation of living things based on their characteristic flourishing that has the same conceptual structure as evaluations of human beings, including evaluations of human action and character.” These value-based approaches to understanding function indirectly support (or suggestively resonate with) our thesis that CSI (including its functional component) is a kind of value.
- ³ Samuel Cusimano and Beckett Sterner (2019, 2) note that in the past few decades, “philosophers of biology shifted away from attempts to provide universal necessary and sufficient conditions and moved toward a pluralist view that recognizes two major senses of function: an etiological account based on a trait’s history of natural selection, and a causal role account based on how parts of a system contribute to a system-level capacity of interest.” We follow this trend.
- ⁴ Leslie Orgel (1973) helped pioneer CSI (see the section “Biological CSI: Information that Guides the Maintenance and Reproduction of Life”) in ways that anticipated some of our account, but he was confused regarding certain elements of CSI. William A. Dembski (1998) provides a better account of CSI, which we have adapted. However, Dembski’s account differs from ours in that it does not deem function to be inherent to CSI. Unlike Dembski, we think specificity is determined by functional requirements. We intend specification to be a matter of mind-independent constraints, grounded in modal facts concerning global possibility space (metaphysical possibility and necessity) and local possibility space (nomological possibility and necessity), depending on the instance of

- CSI in view. We are neutral in this article on how modal facts about possibility and necessity are best understood, whether in terms of (abstract or concrete) possible worlds or in terms of powers.
- ⁵ Our analysis of function is similar to that of Michael L. Wong et al. (2023, 5): “Insofar as processes have causal efficacy over the internal state of a system or its external environment, they can be referred to as functions.” They argue: “Functional information quantifies the state of a system that can adopt numerous different configurations in terms of the information necessary to achieve a specified ‘degree of function,’ where ‘function’ may be as general as stability relative to other states or as specific as the efficiency of a particular enzymatic reaction.” Their “functional information” resembles our CSI. They analyze physical, biological, and cultural forms of functional information (e.g., habitable planet/moon systems, enzymes, and human languages).
 - ⁶ Contemporary information theory and complexity science recognize numerous nonequivalent notions of complexity: algorithmic (Kolmogorov), Shannon, computational, structural, hierarchical, thermodynamic, dynamical, ecological, and probabilistic. Each captures different aspects of organization and generative difficulty. CSI uses probabilistic complexity because it evaluates whether a proposed process has sufficient resources to generate a functionally constrained configuration. Algorithmic complexity is complementary but not a substitute, since compressibility does not correlate with functional constraint or generative feasibility. This pluralism is well documented in Maximilian Barnett (2024), David J. LePoire, Leonid E. Grinin, and Andrey Korotayev (2025), and the broader complexity-science literature.
 - ⁷ The exact shape of each rock in my backyard is rare (unique), but such rarity is not due to tight constraints consistent with functional requirements. Such rarity is largely irrelevant to our project.
 - ⁸ What we have in view here are biological functions, but there could be other metaphysical functions that operate at the level of the whole organism.
 - ⁹ Descriptive complexity (Kolmogorov or algorithmic complexity) is the length of a minimum description that characterizes, or computationally generates, a given pattern. Low descriptive complexity obtains when the observed item can be described more briefly than comparable random noise by means of meaningful contextual knowledge (e.g., a database of comparable items) (see Ewert, Dembski, and Marks II 2015). Algorithmic measures therefore classify random strings as highly complex, even though they lack functional organization. CSI requires not merely complexity but a match to an independently given functional specification, and thus probabilistic complexity is the appropriate concept for assessing whether stochastic physical processes can generate such functional organization. This explains why algorithmic complexity and CSI complexity do not coincide.
 - ¹⁰ Lewis and Barnes (2016, 109) indicate that gravity is fine-tuning to one part in 10^{35} (not 10^{60}). Regardless of the exact number, the extreme rarity of cosmic life-friendliness is well established.
 - ¹¹ Anthropic selection accounts of fine-tuning, even if they succeed in removing “surprise” about a cosmos fit for life, do not undermine our thesis that such fine-tuning is CSI. Granted, we should not be surprised that we inhabit a cosmos structured with sufficient CSI to make life possible (absent such fine-tuning, we would not exist). Those unimpressed by anthropic accounts often place their bet on the discovery of a small set of cosmic constraints that necessitate the coincidences that constitute life-friendly CSI. That would relocate the primary repository of cosmic CSI to those fundamental constraints.
 - ¹² Other factors include the right timing and amount of delivery of life-critical materials by impacts from space objects and the right planetary rotation rate in conjunction with other parameters (Lammer et al. 2009). Moons and giant planets are even less likely to be habitable than small rocky planets for many other reasons, as Helmet Lammer et al. (2009) show.
 - ¹³ We allow that biological life might be valuable for other reasons not connected to its instantiation of CSI. Minimally, however, our argument shows that CSI is a partial ground, if not a total ground, of the value of biological life.
 - ¹⁴ Mario De Caro and David Macarthur’s (2010) anthology focuses on options in the space between strict scientific naturalism (which typically denies real normativity) and Platonism. “Liberal naturalism” is suggested as an appropriate label for many of the positions that stake a claim within that middle ground.
 - ¹⁵ Some proteins are not as rare as Axe’s estimate, but they perform very simple functions. Most proteins are extremely rare, as various studies show (Tian and Best 2017; Reidhaar-Olson and Sauer 1990).
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