Interdisciplinary Description of Complex Systems 21(1), 1-17, 2023

COLLAPSING THE COMPLICATED/COMPLEX DISTINCTION: IT'S COMPLEXITY ALL THE WAY DOWN

Ragnar van der Merwe

University of Johannesburg, Department of Philosophy, Faculty of Humanities
Johannesburg, The Republic of South Africa

DOI: 10.7906/indecs.21.1.1
Regular article

Received: 15 July 2022.
Accepted: 21 February 2023.

ABSTRACT

Several complexity theorists draw a sharp and ontologically robust distinction between (merely) complicated systems and (genuinely) complex systems. I argue that this distinction does not hold. Upon fine-grained analysis, ostensibly complicated systems turn out to be complex systems. The purported boundary between the complicated and the complex appears to be vague rather than sharp. Systems are complex by degrees.

KEY WORDS

complex systems, complexity theory, Stuart Kauffman, Sandra Mitchell, Edgar Morin

CLASSIFICATION

JEL: C51

*Corresponding author, η: ragnarvdm@gmail.com; -;
University of Johannesburg, Department of Philosophy, Faculty of Humanities, Kingsway Campus, Corner Kingsway and University Road, Auckland Park, Johannesburg, 2000, The Republic of South Africa

INTRODUCTION

Is the world *complex* or are only parts of the world complex? One's answer to this question has significant implications in both science and philosophy. If the world is complex, then our models, predictions, and manipulations of it will always be partial and limited. This is because complexity, almost by definition, implies some recalcitrance to epistemic capture. However, if only parts of the world are complex – if some parts are merely *complicated* – then we can presumably come to model, predict, and manipulate the complicated parts precisely. Although the above question has these epistemic consequences, the answer itself relates to ontology. I will however limit my discussion to *systems* rather than make ontological claims about the world as a whole. So, the question at hand becomes "are systems complex or are some systems complex while others are complicated?" The same consequences follow, but specifically as they relate to systems.

We can take systems to be that which constitutes the subject matter of science. As Sandra Mitchell states, "[c]ontemporary science studies complex structures and behaviors at a variety of levels of organization ... using representations of different degrees of precision, from fine- to coarse-grained" [1; p.178]. On my account, a system is not a fundamental entity or structure. Fundamental entities or structures (assuming there are such things) are not standardly categorised as either complicated or complex. This dichotomy is applied to systems, and that will be my focus here. If some scientists are studying fundamental entities and structures (a matter that is open to debate), then my argument will not apply to whatever their subject matter is (quantum particles and forces or supersymmetric string perhaps).

Systems do though seem to be composed of or structured out of whatever *is* fundamental. Roughly, one might think of systems as 'clumps' (or what Edgar Morin calls a "tangle" [2; p.84]) of whatever is fundamental. Systems are the clumps of world stuff studied by scientists not engaged in fundamental ontological inquiry. This should be relatively uncontroversial. I am not aware of any thesis that posits systems as fundamental. I think most would agree that systems are what is usually called *emergent*. They emerge from some thing(s) and/or process(es) more fundamental. I will though not discuss emergence in any detail here (see however [2] and [3]). Emergence is a big philosophical topic that is beyond the scope of this article. Nonetheless, we can debate the nature of systems without considering exactly how they emerge. My direct concern is with whether systems are complicated or complex, and not with how they come about. My argument is that systems appear to be complex by degrees rather than divided into complicated and complex types.

Several writers contributing to the complexity literature draw a sharp and ontologically robust – i.e. joint-carving – distinction between (genuinely) complex systems and (merely) complicated systems.

> *Complex systems:* It is questionable whether 'complex system' can be defined by a single and neatly comprehensible term [1-3]. However, following Richardson and Cilliers, a complex system is roughly a "a system that is comprised of a large number of entities that display a high level of nonlinear interactivity" [4; p.8] (emphasis removed). Most importantly, complex systems are systems whose behaviour is irreducible to any comprehensible algorithm, set of rules, or simpler constituent parts. Complex systems are recalcitrant to exact modelling, prediction, or manipulation, and they cannot be understood completely. Our epistemic grasp on complex systems is necessarily partial and limited. We cannot know whether the parts of a complex system we isolate during modelling constitute the essential characteristics of that system.

> *Complicated systems:* Complicated systems are systems that may appear complex but are, in fact, simple. Their behaviour is reducible to some comprehensible algorithm, set of rules, or simpler constituent parts. Complicated systems can, in principle, be modelled, predicted, manipulated, and understood precisely.

I will call the purported distinction between complex systems and complicated systems *CCD*.

According to Paul Cilliers, when it comes to complicated systems, "if you work hard enough, with clever enough techniques, you can figure the system out" [5; p.7]. In contrast, "grappling" with complex systems "requires a more reflexive and transformative approach" [5; p.7]. For Cilliers, we should recognise and even embrace the indubitable partiality and limitedness involved in our inquiries into the nature of complex systems. According to Minka Woermann and colleagues [6], complicated systems are dealt with in the "restricted paradigm", while complex systems are dealt with in the "general paradigm".

> In the restricted paradigm, complex systems are epistemically complex but ontologically complicated. We might think that some system is genuinely complex, but, upon analysis, it turns out to be merely complicated.
>
> In the general paradigm, complex systems are both epistemically and ontologically complex. No matter what clever techniques we employ, we can never isolate the system in order to model, predict, and manipulate it completely.

Note that proponents of CCD are not merely making the epistemic claim that our theories or models draw a distinction between complicated systems and complex systems. Instead, they are making the metaphysical claim that systems have a dualistic constitution; two types of systems exist: complicated and complex ones. CCD is thus manifestly ontological. As such, my argument does not apply to those who think that a distinction between complicated systems and complex systems is an epistemic placeholder, heuristic convenience, or practical aid that we utilise while inquiring into and interacting with the world. We may successfully employ different theoretical structures or modelling methods in different domains of inquiry, but we should be cautious of extrapolating from an epistemic demarcation to a robust ontological one. Even those who peg their ontological commitments to our best current science, invariably remain fallibilists about such commitments given that the history of science is littered with discarded ontologies and given that science has evidently not reached any ideal end of inquiry [7-9] (I return to this topic in the section titled 'Ontological Foundationalism is Indefensible')[1].

Some may wonder in what sense a system can be regarded as epistemically complicated if all systems are supposed to be ontologically complex. How can we talk about complexity if we do not provide a clear definition of a complicated system? My focus here is on the ontological conception of CCD because proponents of CCD consider it to be first-and-foremost an ontological question whether a system is complicated versus complex. Proponents of CCD maintain that CCD holds both epistemically and ontologically, while I think that it only holds epistemically. I certainly do not intend to deny the *usefulness* of the complicated/complex dichotomy. That said, I am focusing on ontology since I have no disagreement with proponents of CCD when it comes to epistemology.

A full-fledged account of the epistemology of CCD would require its own paper length treatment. Briefly though, a pragmatist approach may be suitable for articulating in what sense CCD can be epistemic but not ontological. A system is epistemically complicated versus complex when treating it as one or the other results in successful novel predictions and/or useful applications (e.g. accurate weather forecasts or efficacious vaccines). What does it mean to *treat* a system as complicated versus complex? Roughly, a system is epistemically complicated if the theories or models we use when successfully predicting or manipulating the system depict (characterise or idealise) it as being reducible to some comprehensible algorithm, set of rules, or simpler constituent parts. In contrast, a system is epistemically complex if the theories or models we use when successfully predicting or manipulating the system depict (characterise or idealise) it as being irreducible to some comprehensible algorithm, set of rules, or simpler constituent parts. This description leaves open systems' ontological status, which, as mentioned, is my focus in this article. As we will see, probing the ontological issue requires fine-grained investigation of whatever system is purported to be complicated versus complex.

In any event, my goal in this article is to call CCD into question and then suggest a way to make sense of the proceeding ontological repercussions. I argue that those who advocate for CCD face the following problem. CCD cannot be drawn at any discernible location. Some proponents of CCD attempt to draw the distinction at the boundary between living and non-living systems or between physical and non-physical systems. As we will see, both are prone to demonstrable counterexamples. I argue that CCD therefore constitutes a vague rather than sharp demarcation. If so, then systems are either complicated all the way down or complex all the way down. I argue for the latter, at least down to the quantum level.

Note also that I will focus on so-called physical systems (systems that are not abstract or normative), and I therefore side-line the question of whether mathematical and ethical systems might be complicated versus complex. I will also regrettably gloss over much of the important technical work being done in the study of complex systems. Being a philosophical investigation, rather than a scientific or computational one, this article engages with its subject matters at varying levels of abstraction across different domains of inquiry.

The outline of this article is as follows. In the first section, I introduce and explicate CCD. In the second section, I argue that CCD is vague rather than sharp. In the third section, I engage with three possible objections to my argument.

CCD: COMPLICATED VERSUS COMPLEX SYSTEMS

The purpose of this section is to introduce CCD and the various writers who advocate for it. I pay special attention to CCD's ontological nature, to the idea that it putatively carves nature at the joint/s.

According to Roberto Poli, complex systems contrast with complicated systems because complicated systems can be managed or controlled through the implementation of appropriate interventions, while complex systems need to be "systematically managed and any intervention merges into new problems as a result of the interventions dealing with them ... [T]he relevant systems cannot be controlled" [10; p.142].

Several post-structural complexity theorists – see notably Cilliers [11] and Woermann [12] – also subscribe to CCD. Cilliers and Woermann are particularly critical of what they call the "rule based" or "analytic approach" to the study of complex systems. The analytic approach, they claim, makes the mistake of treating complex systems as complicated systems. According to Woermann, those subscribing to the analytic approach aim, but fail, to "uncover the laws and rules of our complex realities and to develop mathematical formalisms to describe complex behaviour ..." [12; p.41]. Cilliers considers the work of Noam Chomsky, Jerry Fodor, Jürgen Habermas, and John Searle to be exemplary of the analytic approach. This is because they attempt to reduce complex semantic or linguistic systems to formal rules. According to Woermann [12; Ch.2], even general systems theory and cybernetics subscribe to the analytic approach. In the former, complex systems are reduced to the concept of "organisation"; in the latter to the metaphor of "the machine".

In their advocation of CCD, Cilliers and Woermann draw specifically on the work of Edgar Morin. Morin states that complexity obtains

> wherever one finds a tangle of actions, interactions, and feedback. And this tangle is such that, even with the aid of a computer, it would be *impossible* to grasp all of the processes involved [2; p.84] (emphasis added).

This contrasts to mere complicatedness where it would be *possible* to grasp all of the processes involved. For proponents of CCD, complexity is thus *in principle* irreducible to something simpler, while complicatedness is *in principle* reducible to something simpler (even if we might not currently possess the means to do so). In a slogan, a system is genuinely complex if the whole is greater than the sum of its parts, while a system is merely complicated if the whole is identical to or less than the sum of its parts [12-16].

An anonymous reviewer pointed out that, from the standpoint of the history of ideas, such a view is difficult to make sense of. Traditionally, any system is regarded as more than the mere sum of its parts because of its emergent properties. I agree with the reviewer that the view is difficult to make sense of. Hence, my compulsion to write this article. The view is though surprisingly widespread. When reading the complexity literature, it is not uncommon to come across the idea that some systems are more than the sum of their parts while others are identical to – nothing more than – the sum of their parts.

Stuart Kauffman's influential work on radical emergence is a notable example (see e.g. [16]). For Kauffman, biological systems have genuinely (i.e. ontologically or radically) emergent properties. Being alive is such a property. Biological systems are thus greater than the sum of their parts. In contrast, Kauffman considers physical systems – notably systems that obey Newton's laws – to be nothing more than a collection of constituents. Physical systems are thus not greater than the sum of their parts (not in the ontological sense we are concerned with). Kauffman's physical/biological distinction roughly maps onto the complicated/complex distinction we are concerned with. For Kauffman, biological properties, like being alive, are genuinely (ontologically or radically) emergent, while physical properties, like travelling through space along a parabolic trajectory, are not. I return to Kauffman's view in the section titled 'Physical versus Non-Physical Domains'.

According to Cilliers, examples of complicated systems include motor cars, jumbo jets, computers, and snowflakes. Examples of complex systems include living organisms, language, society, and the brain [11; Ch.1, 17; pp.41-42]. The former would then not possess ontologically significant emergent properties; they are nothing over and above the mechanical goings on of their constituent parts obeying simple laws. The latter would though possess ontologically significant emergent properties (what Kauffman [16] would call "radically emergent" properties); they are more than the sum of their parts.

Central to understanding CCD is the putative distinction between *closed* systems and *open* systems. Complicated systems, on the one hand, are closed; they are isolatable and therefore formally tractable. Complex systems, on the other hand, are open to their environment, including other complex systems; they are not formally tractable [11; pp.9-10] (see also [6, 10]). Importantly, proponents of CCD further consider the difference between closed and open systems – i.e. between complicated and complex systems – to be one of *type* and not of *degree*. There is then supposed to be a *sharp*, rather than a *vague* or *fuzzy*, demarcation between complicated and the complex systems. Preiser and Woermann [18] list various texts that "very convincingly" defend the idea that CCD is ontologically sharp. These include [10, 11, 19-22] (see also [6; pp.5-7]). What these texts have in common, according to Preiser and Woermann, is that they

> dispel the notion that the distinction is superficial (i.e. merely a matter of perspective or subjective interpretation). Instead, they argue that the distinction hinges on an order difference between complex and complicated phenomena [18; p.17].

On such accounts, a system is either closed or it is open, and not a bit of both. A system cannot be partly reducible and partly irreducible (whether to a comprehensible algorithm, set of rules, or simpler constituent parts).

Having introduced CCD, I now argue that it does not hold in a strict ontological sense. It does not denote a genuine metaphysical demarcation; it does not carve nature at the joint/s. I will not argue that a system can be both closed and open or that a system can be partly reducible and partly irreducible. Instead, I will argue that CCD cannot be unproblematically drawn at any specific location. If so, proponents of CCD should abandon their ontological dualism (even if they may wish to maintain a weaker epistemic, heuristic, or pragmatic kind of dualism).

CCD: A FALSE DICHOTOMY

In this section, I argue that the world is not divided into complicated versus complex systems. On fine-grained analysis, it is demonstrable that CCD is vague rather than sharp. Advocates for CCD are not always clear on what kinds of systems belong in the complicated versus the complex categories. In making my argument, I nonetheless focus on the two places where CCD is sometimes drawn. Firstly, the putative living/non-living demarcation, and, secondly, the putative physical/non-physical demarcation.

LIVING VERSUS NON-LIVING DOMAINS

For some, non-living systems are complicated systems, while living systems are complex systems [11; p.3, 12; p.185]. One obvious counterexample is the Earth's weather and climate systems. Such systems are non-living, and, if CCD maps onto the living/non-living distinction, then they should count as merely complicated. Earth's weather and climate systems are however widely considered to be complex systems because they are irreducible to simple rules, open to their environment, cannot be precisely modelled or predicted etc. [3].

Another example is computational systems. Michael Dillon [23] argues that modern computer software systems are complex systems even while they are (presumably) not alive. Such systems, he says, are "powerfully capable of self-adaptation and self-propagation... [The] distinction between the organic and the non-organic breaks down" [23; p.12]. Although most of us do not think of computer software programs as being alive (not yet anyway), they do display certain features normally associated with life. As Dillon points out, they seem to evolve (self-adaptat) and reproduce (self-propagate), at least in some minimal sense. Computer software programs are perhaps quasi-living (see also [16; epilogue, 3; pp.124-125]).

Moreover, if CCD equates to the living/non-living distinction, then there must be some way in which the merely complicated transmogrifies into the genuinely complex. There must be some ontological 'jump' from non-living to living that occurs in both ontogenetic and phylogenetic development. There is however no evidence from embryology or evolutionary biology for such a jump. Both ontogeny and phylogeny are gradual processes, even if there are periods of relative stasis versus relative rapidity [24, 25]. A living thing is not complicated one moment, then suddenly complex the next. There is no clear moment in the ontogenetic or phylogenetic history of living things where something like CCD could reside. In conclusion, it appears that CCD cannot be successfully mapped onto the putative living/non-living distinction.

As before, it may be useful or goal-attaining for scientists to *talk* of living versus non-living systems. We should however not mistake (even our best) theories or models of the world for the world itself. As mentioned in the introduction, to do so is to abandon the fallibilism rooted in the scientific method. It involves making the tacit claim that science cannot progress any further in its attempts to uncover the nature of the world (I return to this topic in the section titled 'Ontological Foundationalism is Indefensible'). Few would, I take it, want to bite this bullet.

PHYSICAL VERSUS NON-PHYSICAL DOMAINS

The idea that CCD can be drawn at the putative living/non-living demarcation seems fairly easily dismissible. It is however more common to draw CCD at the putative demarcation between what is physical versus non-physical. This is roughly equivalent to the putative material/non-material demarcation. According to Poli, CCD delineates the material from the psychological and the social: "the material stratum should be termed *simple* [approx. complicated], while the psychological stratum and the social stratum are *complex*" [26; p.12] (original emphasis).

As mentioned, Cilliers considers a motor car to be an exemplary complicated system. This is because a motor car is purportedly not more than the sum of its parts. It can be reduced to and understood in terms of something(s) simpler. However, when we look closely, a motor car is continuously interacting with its environment. Like all things, a motor car's composition and form changes over time. The body will rust, the tyres will degrade, and so on in a way that is unpredictable, non-linear, and ostensibly ungoverned by deterministic laws. There is ongoing micro-physical activity at the interface of any object and its environment that, ontologically speaking, renders that object *de facto* an open system. At the micro-level, chemicals are interacting, atoms are bonding, and various quantum events are ongoing. These include particle annihilation and creation (not to mention entanglement, decoherence and tunnelling). Mostly, the motor car slowly disintegrates, of course. Yet, there can also be moments of construction (or 'creativity') caused by chemical reactions and/or quantum effects. This can occur even while the system (like all systems) on-average obeys the 2nd law of thermodynamics. Events and processes usually associated with complexity (recall the definition in the introduction) can occur within an object, between an object and its environment, and between outwardly different objects.

The above suggests that a motor car is, in fact, a complex system (even if only minimally complex) that is evolving and adapting to its environment at the physical and chemical level [2, 27, 28]. What appear to be complicated systems at the macro-level, are then complex systems at the micro-level. James Ladyman and Karoline Wiesner make a similar point regarding the gravitational interconnectedness of so-called physical objects:

> A gas in a container at equilibrium can be treated as a closed system, as can systems of condensed matter, even though they are really interacting through gravitation with the rest of the universe because the effects of it on them are so small [3; p.29][2].

Systems can be epistemically closed (merely complicated), even while they are ontologically open (genuinely complex).

A motor car appears to be merely complicated at a certain level of course-graining. Yet, when we zoom in and inspect it in fine-grained detail, it reveals itself to be genuinely complex. Cilliers' claim that motor cars, jumbo jets, computers, and snowflakes are complicated systems while living organisms, language, society, and the brain are complex systems only holds at a certain level (or scale or degree of resolution) where certain kinds of theories and models apply. To make definitive ontological claims, we should though surely consider all levels of analysis. If we do not look closer, we may be missing something important. Cilliers appears to be cherry-picking his preferred level of analysis in a way that neatly supports CCD.

To press the point, consider H_2O. Even a supposedly simple (merely complicated) H_2O molecule has emergent qualities or properties – e.g. viscosity and solvency – that its H and O atoms do not have individually. An H_2O molecule can therefore be considered a complex system: it cannot be reduced to simpler constituents without losing some of what makes it H_2O in the first place. As Woermann notes, in such cases "systemic attributes cannot be reduced to the parts alone, but are the result of interconnections between the parts" [12; p.36] (see also [21]). The whole (the H_2O molecule) is greater that sum of its parts (the H and O atoms that bond to form H_2O) (see also [29; pp.84-86, 30; p.240])[3].

At times, Morin even thinks of so-called fundamental particles as complex systems. A fundamental particle, like an electron, he says, “is not a simple primary unit ... It oscillates between being and nonbeing, between wave and particle” [13; p.130] (see also [7]). Even a quark, claims Morin, can be thought of as a complex system given that, according to standard particle physics, it as a “fuzzy entity that cannot be isolated” [2; p.40]. In the “micro-physical world, what we see is a cloud of indeterminacies from which we can derive only a statistical orderliness” [2; p.87] (see also [28; epilogue]). If quantum processes apply to all objects – as standard quantum theory suggests [31] – then it may be that all objects exhibit features of complexity when examined at a suitably fine-grained resolution.

Now, we need not follow Morin in speculating about the metaphysical nature of electrons and quarks to collapse CCD. Whether electrons and quarks are complicated versus complex is a question we can leave to quantum physicists and philosophers of quantum physics. The debate around the ontology of quantum physics is ongoing (see [9, 32] for an overview). Questions related to non-locality, hidden variables, and the ontological status of the wave function are, for now, a matter of philosophical interpretation rather than textbook fact. Sound answers to these questions would bear on whether there is complicatedness versus complexity at the quantum level, but I do not think that there is sufficient clarity at this point to take a definitive stand either way.

To my knowledge, no proponents of CCD anyway advance the idea that complicated systems make up the ontology of quantum physics, while complex systems make up everything else (perhaps some string theorists would say this). In any event, even if the ontology of fundamental physics is complicated while everything else is complex, the version of CCD advanced by the writers mentioned in the first section still collapses. This suffices for our purposes. We might say that *systems are complex all the way down, at least down to the quantum level (about which we can remain agnostic for now).*

We can nonetheless engage with an argument made by Kauffman for a sharp kind of physical/non-physical ontological dualism that roughly maps onto CCD. Kauffman’s argument proceeds as follows: “the universe has made all the possible types of stable atoms” (the bosons and fermions that make up the ontology of particle physics) [16; p.2]. The universe has however made only a “tiny fraction [of] all possible complex things” (e.g. proteins, organisms, economic markets, and computer software systems); the universe can never make all possible complex things [16; p.3]. This suggests to Kauffman that the world consists in two distinct ontological domains: one made up of non-complex, physical, or *ergodic* systems and the other made up of complex, non-physical, or *non-ergodic* systems. An ergodic system “visits all its possible states over some ‘reasonable’ time period”, while a non-ergodic system “does not visit all its possible states” [16; p.4] (see also [33; Ch.7, 34; Chs.2-3]).

Kauffman’s dualism relates to a distinction between, on the one hand, the (non-complex/ergodic) ontology of general particle physics (which includes but is not identical to quantum physics), and, on the other hand, the (complex/non-ergodic) ontology studied in biology and other so-called higher-level sciences. Kauffman does not refer to ergodic systems as complicated systems. He does nonetheless think of them as obeying deterministic laws and as exhibiting precisely predictable behaviour. This is sufficiently similar to the way that advocates for CCD define ‘complicated’.

In any event, Kauffman thinks that the ontology of physics is ergodic because, when investigating some system of interest, physicists work with a prestated phase space wherein the evolution of the system is logically entailed in the initial conditions and deterministic laws. The system’s behaviour is, in principle, precisely knowable, predictable, and manipulable. Conversely, there is no prestatable phase space and there are no deterministic laws in biology; “ever-new functions constitute the ever-changing phase space of biological evolution” [34; p.70] (see also [14]).

The systems that make up the ontology of biology are continuously changing their states, says Kaufmann, and this contingency is not evident in the linear behaviour of systems composing the ontology of physics. This is what it means for biological systems (like economic and technological systems) to be non-ergodic. A non-ergodic system's behaviour is, in principle, only partially knowable, predictable, and manipulable.

Given the above, we can say that an ergodic system's behaviour is *necessarily* one way rather than another, while a non-ergodic system's behaviour is *contingently* one way rather than another. As with CCD, for Kauffman, the ergodic/non-ergodic dichotomy is not the result of contingencies in scientific methodologies; it is not epistemic. Instead, it is a qualitative ontological distinction that obtains 'out there' independent of whatever theories or models scientists employ during inquiry [33; Ch.2]. Regarding non-ergodic systems, "the parts exist for and by means of the whole" [16; p.8]; the whole is greater than the sum of its parts. Conversely, in ergodic systems, the whole is less than or equal to the sum of its parts.

Kauffman thinks of biological organisms as non-ergodic systems; they are complex systems composed of sustaining subsystems. He calls such systems "Kantian wholes". Kantian wholes are "autopoietic systems" that "build themselves" [34; Ch.4] (see also [14]). Although Kantian wholes have physical energy and particles as input, they are not themselves physical. They are "based on physics, but beyond physics" [16; p.127] (see also [22]).

As before, there are reasons to question Kauffman's strict ontological dualism. There appear to be vague cases that cannot be easily sorted into either the ergodic or non-ergodic category. Sandra Mitchell has argued along these lines. Contra CCD, she claims that the laws that apply in physics compared to biology are not qualitatively different; they vary "in degree – not in kind" [35; p.62]. Mitchell's argument is clear and on-point, and therefore worth quoting in full:

> many of the relationships connecting physical properties and events are more stable than are the relationships connecting biological properties and events. What stability denotes is the degree of invariance of a relationship between events or properties that are represented in scientific generalizations. The traditional view of laws required that stability be implacable. The relationship between mass, distance, and gravitational attraction would hold, come what may. But stability varies. Some structures are more stable than others, are less vulnerable to being disrupted by what occurs in their neighborhood, but few, if any, satisfy the strictest conditions of exceptionless universality. There is a difference between fundamental physics and the biological and social sciences – but it is not the difference of a domain of laws versus a domain of accidents [35; p.62].

Mitchell considers all scientific laws to be *ceteris paribus* laws. They only hold given whatever contextual suppositions and boundary conditions apply. Any scientific truth, says Mitchell, "describes events that could have been otherwise, whether it is about the physical constituents of our world or the biological ones" [35; p.57]. The so-called physical and the so-called biological are, in this sense, then modally indistinguishable. Thus,

> the 'laws' of physics and the 'laws' of biology are both strictly contingent; their truth depends not on logical form or definition, but on whether they accurately represent our world. There are differences, but they are differences in degree and origin, and not in logical kind ... The lawful relationship between free-falling bodies and the earth and parent and gamete frequency have different degrees of stability and scope, which affects the degree to which we can depend on them holding in many contexts ... The stability of the conditions upon which a causal relationship depends establishes a continuum, rather than a dichotomously partitioned space of the necessary and the contingent [35; pp.57-58] (see also [1]).

Although Mitchell is not engaging with Kauffman directly, her argument appears to be a powerful counter to his style of ontological dualism (see also [36-38]). Physicists and biologists may model and theorise about the world in different ways – they have different epistemic conceptions of things – but this does not entail that the world must *de facto* be constituted in those different ways. Mitchell's critique of the supposed demarcation between physics and biology suggests that they are not as different as Kauffman supposes.

Kauffman also appears to be working with an outdated conception of physics. In his writings, he repeatedly equates physics *simpliciter* with Newtonian physics. Contemporary physics is however not limited to Newtonian methods. It is a diverse field where different kinds of equations and models are applied in different contexts to generate ostensibly different ontologies, all of which do not obviously fit on the ergodic side of Kauffman's ergodic/non-ergodic divide. Kauffman writes, for example,

> [i]n physics, one always prestates the phase space of a system. For Newton, given his three laws of motion, the phase space is defined by the boundary conditions, for example, the boundaries provided by a billiard table. Given these, we can define what we call the phase space of all possible positions and momenta – every way the balls can move on the table. Then we write Newton's laws in the form of differential equations; and from the initial and boundary conditions, we solve for the trajectories of the balls by integrating the equations [16; p.126].

Notice how Kauffman conflates physics with Newtonian physics. Doing so excludes contemporary fields in the physics of information and in non-equilibrium and quantum thermodynamics. Here, the focus is on the structure, patterns, and the potentiality of physical things (systems in our case). The notion of work, for example, can be defined in term of its usefulness or its potential to generate energy. That is, work is defined relative to a context rather than in strictly mechanistic or linear terms, and the outcome of one's inquiry will likewise be relative to that context. This is oddly similar to how biology and other non-physical sciences are supposed to operate on Kauffman's account. Kauffman's artificially narrow definition of physics rigs the game in favour of his version of CCD.

In sum then, it seems that – as with the putative living/non-living demarcation – CCD cannot be drawn at the putative physical/non-physical demarcation. There may be other places where one could attempt draw CCD, but I suspect that fine-grained analysis would once again uncover vagueness rather than sharpness.

POSSIBLE OBJECTIONS

The above suggests that there is no clear location in space or time where CCD might reside, and that ontological analysis of various systems at various degrees of resolution invariably uncovers complexity (at least down to the quantum level). I now engage with three possible responses sceptics might make to my argument.

COMPLICATEDNESS RATHER THAN COMPLEXITY ALL THE WAY DOWN

If CCD collapses, some might want to say that there are complicated, rather than complex, systems all the way down. It would certainly be more convenient – inquiry would be simpler – if this were the case. We could then, in principle, come to understand all systems and not just some of them. To make such a claim is however to take on the massive burden of demonstrating how highly complex systems – like the brain (or the economy or the climate) – can be reduced to a simple algorithm, set of rules, or simpler constituent parts. Efforts to do so are ongoing, but there does not appear to be any clear end in sight. Stating that such a reduction is possible requires some formal proof, a proof that is currently absent (see [39, 40] for more on reductionism in science and philosophy). Given my aforementioned arguments, it seems far more likely that there are complex systems all the way down (at least down to the quantum level).

Thinking along similar lines, Michael McGuire states that it is "plausible that [we] should allow for complexity to go 'all the way down'. That is, [we] ought to allow for infinite nesting of objects within objects, not metaphysical full stops" [41; p.189] (see also [35]). CCD implies metaphysical full stops, while I have suggested something like an infinite nesting of objects. Complex systems are, not only entwined with other complex systems, but they can also be imbedded in each other (something like Russian dolls)[4]. The brain, for example, is a complex system, but it has complex sub-systems imbedded in it, which, in turn, have complex sub-subsystems imbedded in them. Larry Swanson and colleagues [42] think of the brain as a "clustering hierarchy" or a "connectivity hub". Focusing specifically on the endbrain in rats, they claim that employing a multiresolution consensus clustering (MRCC) method

> provides a hierarchical description of community clustering (modules or subsystems) within the ... global network organization of axonal macroconnections between the 244 regions forming the endbrain ... [42; p.E6910].

The clusterings (modules or subsystems) within the global network organisation composing the endbrain are then composed of further clusterings etc. This suggests that the brain consists in a hierarchical nesting structure – "a hierarchy of subsystems" – in which

> there are 60 subsystems at the bottom of the hierarchy, and they combine in specific ways through 50 levels of the hierarchy branching pattern ... to form just four primary subsystems at the top level [42; p.E6919] (Swanson et al. [43] develop a similar hierarchical schema for the midbrain).

Swanson et al. find that the top-most clusterings in this hierarchy are highly complex, but get simpler down the levels (see also [44]). In other words, the brain consists in a hierarchy of complex systems nested inside further complex systems, and the degree of complexity diminishes down the hierarchy. Like many things, complexity naturally comes in degrees [27, 35; pp.55-57]. Swanson et al. do not discuss what occurs at the micro-biological or chemical levels. As argued above, we can though infer that there are further complex systems underpinning the bottom level of their endbrain hierarchy, and so on.

As we zoom in and out to differing degrees of course- versus fine-grained resolution, all systems seem to fit the definition of 'complex system' (at least down to the quantum level). These is a graded rather than strict demarcation between ostensibly complicated systems and complex systems, and CCD thereby collapses. One who does not consider all levels or scales when making ontological posits, will necessarily develop an oversimplified and parochial ontology that misses the complexity that reveals itself when we do.

CONTEXT DETERMINES WHETHER SOMETHING IS COMPLICATED VERSUS COMPLEX

A further possible response is that there is an inescapable contextuality inherent in our ontological investigations and proceeding ontological conclusions. We unavoidably adopt some context-relative *perspective* during ontological inquiry, where a perspective is a general outlook, attitude, or point-of-view incorporating a specific methodology or approach towards ontological inquiry (roughly what Kuhn [45] calls a "paradigm" or what van Fraassen [46] calls a "stance") (See the collection in [47] for the status of the current debate around perspectives and perspectivism). Thus, the ontologies we uncover are necessarily indexed to some contingent perspective. Ontological pluralism (or even relativism) follows (see e.g. [11, 12, 48-50]). The ontological pluralist might claim that some system is complicated versus complex relative to whatever perspective the ontologist adopts. Some system can be complicated relative to perspective$_1$ but complex relative to perspective$_2$. This is a weaker version of CCD, a version that nonetheless contradicts my argument.

However, recall that one of my goals in this article is to investigate whether CCD denotes a genuine ontological demarcation in the world, and not merely an epistemic one. We must be careful not to mistake our theories or models of the world for the world itself. This is where the ontological pluralist seems to go wrong. To introduce perspectives into a discussion about ontology is to shift the focus from ontology to epistemology. We want to know whether CCD actually – i.e. ontologically – obtains in the world (in the way that proponents of CCD claim it does). Thus, it is unhelpful to say that it depends on what (epistemic) perspective one adopts. At least when it comes to CCD, the ontological pluralist seems to have missed the point.

To illustrate, let us return to the motor car example. An ontological pluralist would, I think, say that the motor car is *complicated* at the level of medium-sized dry goods but *complex* at the level of chemistry or physics. The motor car is complicated or complex depending on perspective. The problem with such a claim is that it suggests that the ontological constitution of the world (and not just our models of the world) changes – even changes radically – depending on the manner in which *we* investigate it. If I investigate a motor car from an arm's length, then it would *in itself* be complicated. Yet, if I use a high-powered microscope to zoom in and investigate the motor car up close, then it would *in itself* be complex. Then, if I zoom out to arm's length again, the motor car would return to *in itself* being complicated.

If this is the case, then one wonders what ontological constitution the motor car has when no one is looking, or when one ontologist investigates it from arms-length while another *simultaneously* investigates it up close. Might it perhaps enter a superposition of states, a kind of complicated/complex duality? Flippancies aside, the ontological pluralist's possible reply to my argument is grossly counter-intuitive. While it is standardly accepted that we do, to some degree, influence and possibly change some subject matter when we investigate it through empirical means (notably in quantum physics), few would, I take it, claim that the degree of resolution we employ while investigating some system can change that system *in itself* from complicated to complex and back to complicated again.

My quick dismissal of ontological pluralism should not be mistaken for misappropriated boldness. As a general philosophical thesis, ontological pluralism is often supported by thoughtful and weighty arguments (see notably [35, 51]). However, such arguments largely rely on calling into question the idea that ontology can be separated from epistemology (think Kuhn [45] and Hanson's [52] theory-ladenness of observation thesis). There may indeed be good reasons to do so (see [53]). However, this issue does not seem to apply here given that we have followed proponents of CCD in taking it as a strictly ontological question whether a system is complicated versus complex.

ONTOLOGICAL FOUNDATIONALISM IS INDEFENSIBLE

The third objection is one that was made by one of the anonymous reviewers. The reviewer agrees with my criticism of Cilliers and Kauffman when they mistake certain models of the world for the world itself. However, the reviewer thinks that the same kind of criticism can be levelled against me. The reviewer asks why my ontological view should be taken as definitive and absolute truth. My ontological foundationalism is indefensible because it does not take into account the fallibility and historical variability of the metaphysical presuppositions of science. The reviewer compares my view to Roy Bhaskar's (e.g. [54]) realism about fundamental laws of nature, and suggests that Alan Chalmers' [55] criticism of Bhaskar's view should apply to mine as well.

This is a good point, one that any attempt at ontological inquiry must deal with. However, my account does not involve anything as bold as Bhaskar's realism. It does not involve making claims about what Chalmers refers to as "fundamental laws characterising the generative mechanisms of nature" (55; p.22). I agree with Chalmers when he states,

> real situations are typically too complex for a direct application of fundamental laws to be possible. The motions of a real liquid, the excitation and decay of a molecule, even the real motions of the planets in the solar system, are too complex to be precisely characterised by fundamental laws (55; p.21).

Also, I do not employ any "transcendental deductions" of the sort that Chalmers ascribes to Bhaskar. Rather, my claim is merely that, when we investigate different systems on a case-by-case basis, they appear to be complex rather than complicated (at least down to the quantum level). And, this suggests that the complicated/complex distinction does not hold. My view is thus far more modest than Bhaskar's.

My view is not a form of ontological foundationalism in which I make claims about the ultimate nature of reality. I do not intend to say that reality is fundamentally or intrinsically complex. To say that all systems (at least down to the quantum level) are complex is not to make a claim about the world's ultimate ontological constitution or its fundamental structure. Rather, it is to say that, whatever the world is made of or however the world is ultimately structured, when systems obtain, those systems appear to have a complex constitution. As mentioned in the introduction, my claim is limited to systems.

Regarding the fallibility and historical variability of the metaphysical presuppositions of science, I agree with the reviewer. I do not intend my account to be understood as the conclusive final word on ontology. In the spirit of fallibilism, my claims are open to revision pending disconfirmatory evidence. Once again, my view is modest in this regard.

Although my view is fallibilistic, it is not relativistic. I am not claiming that all systems (at least down to the quantum level) are only complex if we look at things a certain way (the way I do). Rather, my claim is that, given the current state of human knowledge and given the current state of science, fine-grained analysis of any given system will find that system to be complex (at least down to the quantum level). This should not depend on one's perspective or point-of-view. That said, I can only argue from my own point-of-view.

CONCLUSION

Some complexity theorists hold to a sharp and ontologically robust distinction between merely complicated systems and genuinely complex systems. I have called this distinction CCD. I inspected two places where CCD may obtain: the putative living/non-living demarcation and the putative physical/non-physical demarcation. I concluded that CCD does not reside at either, and that it is therefore a vague rather than a sharp distinction. I also analysed various systems (e.g. computational systems, a motor car, and an H_2O molecule). These systems turn out be complex, even if some may appear only complicated at first glance. I also engaged with three possible objections to my argument. I concluded that neither sustains CCD. There may be two ways of theorising about or modelling various systems: a complicated and a complex way. However, this epistemic dualism cannot be transposed onto the world to advance a robust form of ontological dualism.

REMARKS

[1]This is not to say that ontological claims in support of our current best science are necessarily false. It is rather to say that we should not commit to such claims wholeheartedly; we should remain ontological fallibilists. This appears to be the orthodox view amongst scientists and philosophers of science.

[2]Ladyman and Wiesner further suggest that the universe as a whole may be a complex system [3; p.1].

[3]Morin also considers a candle flame to be a complex system because it exhibits non-deterministic, non-linear behaviour [2; p.10] (see also [29; p.239]).
[4]This suggests that complexity may have a fractal nature [27].

REFERENCES

[1] Mitchell, S.D.: *Perspectives, Representation, and Integration*.
In: Massimi, M. and McCoy, C.D., eds.: *Understanding Perspectivism: Scientific Challenges and Methodological Prospects*. Routledge, New York, pp.178-193, 2020,
http://dx.doi.org/10.1007/s11016-020-00501-7,

[2] Morin, E.: *On Complexity*.
Translated by: Kelly, S.M.. Hampton Press, Cresskill, 2008,

[3] Ladyman, J. and Wiesner, K.: *What is a Complex System?*
Yale University Press, New Haven, 2020,

[4] Richardson, K.A.: *Methodological Implications of Complex Systems Approaches to Sociality: Some Further Remarks*.
Journal of Artificial Societies and Social Simulation **5**(2), 1-6, 2002,

[5] Cilliers, P.: *Difference, Identity and Complexity*.
In: Cilliers P. and Preiser, R., eds.: *Complexity, Difference and Identity*. Springer, Dordrecht, pp.3-18, 2010,
http://dx.doi.org/10.1007/978-90-481-9187-1_1,

[6] Woermann, M.; Human, O. and Preiser, R.: *General Complexity: A Philosophical and Critical Perspective*.
Emergence: Complexity and Organization, 2018,

[7] Ladyman, J. and Ross, D.: *Every Thing Must Go*.
Oxford University Press, Oxford, 2007,
http://dx.doi.org/10.1007/s11023-009-9145-7

[8] Wray, K. B.: *Pessimistic Inductions: Four Varieties*.
International Studies in the Philosophy of Science **29**(1), 61-73, 2015,
http://dx.doi.org/10.1080/02698595.2015.1071551,

[9] Peebles, P.J.E.: *Cosmology's Century: An Inside History of Our Modern Understanding of the Universe*.
Princeton University Press, Princeton, 2022,
http://dx.doi.org/10.1515/9780691201665,

[10] Poli, R.: *A Note on the Difference Between Complicated and Complex Social Systems*.
Cadmus **2**(1), 142-147, 2013,

[11] Cilliers, P.: *Complexity and Postmodernism: Understanding Complex Systems*.
Routledge, London, 1998,

[12] Woermann, M.: *Bridging Complexity and Post-Structuralism: Insights and Implications*.
Springer, Cham, 2016,

[13] Morin, E.: *The Concept of System and the Paradigm of Complexity*.
In: Maruyama, M., ed. and trans.: *Context and Complexity: Cultivating Contextual Understanding*. Springer, New York, pp.125-138, 1992,
http://dx.doi.org/10.1007/978-1-4612-2768-7_6,

[14] Longo, G.; Montévil, M. and Kauffman, S.A.: *No Entailing Laws, But Enablement in the Evolution of the Biosphere.*
Proceedings of the 14th International Conference on Genetic and Evolutionary Computation, Conference Companion, 2012,
http://dx.doi.org/10.1145/2330784.2330946,

[15] Santos, G.C.: *Philosophy and Complexity*.
Foundations of Science **18**(4), 681-686, 2013,
http://dx.doi.org/10.1007/s10699-012-9321-8,

[16] Kauffman, S. A.: *A World Beyond Physics: The Emergence and Evolution of Life*. Oxford University Press, New York, 2019,

[17] Cilliers, P. *Rules and Complex Systems*. Emergence **2**(3), 40-50, 2000, http://dx.doi.org/10.1207/S15327000EM0203_04,

[18] Preiser, R. and Woermann, M.: *Introduction*. In: Preiser, R., ed.: *Paul Cilliers, Critical Complexity: Collected Essays*. De Gruyter, Berlin, pp.1-20, 2016, http://dx.doi.org/10.1515/9781501502590-003,

[19] Rosen, R.: *Anticipatory Systems: Philosophical, Mathematical and Methodological Foundations*. Pergamon Press, Oxford, 1985,

[20] Dyke, C.: *The Evolutionary Dynamics of Complex Systems: A Study in Biosocial Complexity*. Oxford University Press, New York, 1988,

[21] Morin, E.: *Restricted Complexity, General Complexity*. In: Gershenson, C.; Aerts, D. and Edmonds, B., eds.: *Worldviews, Science and Us: Philosophy and Complexity*. Translated by Gershenson, C. World Scientific, Singapore, pp.5-29, 2007, http://dx.doi.org/10.1142/9789812707420_0001,

[22] Boogerd, F.C., et al.: *Emergence and its Place in Nature: A Case Study of Biochemical Networks*. Synthese **145**(1), 131-164, 2005, http://dx.doi.org/10.1007/s11229-004-4421-9,

[23] Dillon, M.: *Poststructuralism, Complexity and Poetics*. Theory, Culture and Society **17**(5), 1-26, 2000, http://dx.doi.org/10.1177/0263276405058,

[24] Eldredge, N. and Gould, S.J.: *Punctuated Equilibria: An Alternative to Phyletic Gradualism*. In: Schopf, T.J.M., ed.: *Models in Paleobiology*. Freeman Cooper, San Francisco, pp.82-115, 1972, http://dx.doi.org/10.5531/sd.paleo.7,

[25] Dawkins, R.: *Climbing Mount Improbable*. W.W. Norton & Company, New York, 1996,

[26] Poli, R.: *Three Obstructions: Forms of Causation, Chronotopoids, and Levels of Reality*. Axiomathes **17**(1), 1-18, 2007, http://dx.doi.org/10.1007/s10516-007-9007-y,

[27] Chu, D.; Strand, R. and Fjelland, R.: *Theories of Complexity: Common Denominators of Complex Systems*. Complexity **8**(3), 19-30, 2003, http://dx.doi.org/10.1002/cplx.10059,

[28] Wimsatt, W.C.: *Re-Engineering Philosophy for Limited Beings: Piecewise Approximations to Reality*. Harvard University Press, Cambridge, 2007, http://dx.doi.org/10.2307/j.ctv1pncnrh,

[29] Giere, R.N.: *Scientific Perspectivism*. University of Chicago Press, Chicago, 2006,

[30] Hurst, A.: *Complexity and the Idea of Human Development*. South African Journal of Philosophy **29**(3), 233-252, 2010, http://dx.doi.org/10.4314/sajpem.v29i3.59144,

[31] Davies, P.: *Other Worlds: Space, Superspace, and the Quantum Universe*. Simon & Schuster, New York, 1980,

[32] Myrvold, W.: *Philosophical Issues in Quantum Theory*. In: Zalta, E.N., ed.: *The Stanford Encyclopedia of Philosophy*. 2022, https://plato.stanford.edu/archives/sum2022/entries/qt-issues,

[33] Kauffman, S.A.: *Reinventing the Sacred: A New View of Science, Reason, and Religion*. Basic Books, New York, 2008, http://dx.doi.org/10.1177/1075547009333721,

[34] Kauffman, S.A.: *Humanity in a Creative Universe*.
Oxford University Press, New York, 2016,
[35] Mitchell, S.D.: *Unsimple Truths: Science, Complexity and Policy*.
University of Chicago Press, Chicago, 2009,
[36] Van der Merwe, R.: *Book Review of Stuart Kauffman: A World Beyond Physics: The Emergence and Evolution of Life*.
Metascience **29**(2), 279-282, 2020,
[37] Van der Merwe, R.: *Stuart Kauffman's Metaphysics of the Adjacent Possible: A Critique*.
Interdisciplinary Science Reviews, forthcoming.
[38] Van der Merwe, R.: *On Paul Cilliers' Approach to Complexity: Post-Structuralism Versus Model Exclusivity*.
Interdisciplinary Description of Complex Systems **19**(4), 457-469, 2021,
http://dx.doi.org/10.7906/indecs.19.4.1,
[39] Gillett, C.: *Reduction and Emergence in Science and Philosophy*.
Cambridge University Press, Cambridge, 2016,
[40] Van Riel, R. and Van Gulick, R.: *Scientific Reduction*.
In: Zalta, E.N., ed.: *The Stanford Encyclopedia of Philosophy*. 2019,
https://plato.stanford.edu/archives/spr2019/entries/scientific-reduction,
[41] McGuire, M.: *Some Problems for an Ontology of Complexity*.
In: Gershenson, C.; Aerts, D. and Edmonds, B., eds.: *Worldviews, Science and Us: Philosophy and Complexity*. World Scientific Publishing, Singapore, pp.181-202, 2007,
http://dx.doi.org/10.1142/9789812707420_0012,
[42] Swanson, L.W., et al.: *Subsystem Organization of Axonal Connections Within and Between the Right and Left Cerebral Cortex and Cerebral Nuclei (Endbrain)*.
Proceedings of the National Academy of Sciences **115**(29), E6910-E6919, 2018,
http://dx.doi.org/10.1073/pnas.1807255115,
[43] Swanson, L.W.; Hahn, J.D. and Sporns, O.: *Subsystem Macroarchitecture of the Intrinsic Midbrain Neural Network and its Tectal and Tegmental Subnetworks*.
Proceedings of the National Academy of Sciences **118**(20), E2101869118, 2021,
http://dx.doi.org/10.1073/pnas.210186911,
[44] Miner, D.; Pickett, M. and desJardins, M.: *Understanding the Brain's Emergent Properties*.
Proceedings of the 2nd Conference on Artificial General Intelligence, 2009,
http://dx.doi.org/10.2991/agi.2009.4,
[45] Kuhn, T. S.: *The Structure of Scientific Revolutions*.
University of Chicago Press, Chicago, 1970,
[46] Van Fraassen, B.C.: *The Empirical Stance*.
Yale University Press, New Haven, 2002,
[47] Crețu, A.-M. and Massimi, M., eds.: *Knowledge From a Human Point of View*.
Springer, Cham, 2020,
http://dx.doi.org/10.1007/978-3-030-27041-4,
[48] Longino, H.: *Science as Social Knowledge: Values and Objectivity in Scientific Inquiry*.
Princeton University Press, Princeton, 1990,
[49] Baghramian, M.: *The Virtues of Relativism*.
Aristotelian Society Supplementary Volume **93**(1), 247-269, 2019,
http://dx.doi.org/10.1093/arisup/akz013,
[50] Kusch, M.: *Relativism in the Philosophy of Science*.
Cambridge University Press, Cambridge, 2021,
[51] Chakravartty, A.: *Scientific Ontology: Integrating Naturalized Metaphysics and Voluntarist Epistemology*.
Oxford University Press, Oxford, 2017,
http://dx.doi.org/10.1007/s11016-018-0343-x,
[52] Hanson, N.R.: *Patterns of Discovery*.
Cambridge University Press, Cambridge, 1958,

[53] Van der Merwe, R.: *Whewell's Hylomorphism as a Metaphorical Explanation for How Mind and World Merge*.
Journal for General Philosophy of Science, forthcoming,
[54] Bhaskar, R.: *A Realist Theory of Science*.
Harvester, Sussex, 1980,
[55] Chalmers, A.: *Is Bhaskar's Realism Realistic?*
Radical Philosophy **49**(1), 18-23, 1988.