

The Inefficacy of 'Emergence'

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0. Introduction

Can anything be more than the sum of its parts? The abundance of theories of ‘emergence’ seems to suggest that it can. Each theory of ‘emergence’, in its own particular way, asserts that novel properties ‘emerge’ as a system grows more and more complex. ‘Emergence’ has been attributed to all sorts of phenomena: consciousness ‘emerges’ from the brain; macroeconomic patterns ‘emerge’ from spending patterns; highway traffic ‘emerges’ from driving mentalities, etc. In each of these situations, ‘emergence’ refers to the higher-level order that appears to be irreducible to micro-level behavior. However, not all inexplicable higher-level order is ‘emergent;’ such a claim is not falsifiable, and merely equates ‘emergence’ with our ignorance. In this paper I will do two things: First, I will identify a specific type of system where the higher-level order could be irreducible *only* if it were ‘emergent;’ Second, I will try to determine whether the higher-level order in such systems is truly irreducible.

The structure of this essay is as follows: Section 1 summarizes current definitions of the term ‘emergence,’ from both the philosophers’ and mathematicians’ perspectives. Section 2 presents three paradigmatic instances of inexplicable higher-level order, to give the reader an intuitive feeling for the types of behavior that theories of ‘emergence’ attempt to address. In section 3, I argue that the order seen in these examples can be deemed ‘emergent’ only if there is no other way to explain its existence. Having rigorously formulated criteria for inexplicable order to be ‘emergent,’ section 4 asks the question, “is emergence real?” and eventually I conclude that though ‘emergence’ refers to a specific type of epistemic opacity, ‘emergent’ behavior has no causal efficacy.

1. What is ‘Emergence’?

‘Emergence’ is when the whole is greater than the sum of its parts.¹ ‘Emergence’ is the idea that a system can exhibit properties that have nothing to do with the properties of its component parts. ‘Emergence’ is more than a new system of description at a higher

level of complexity; for a quality to be ‘emergent’ it must be fundamentally new and *require* explanation at a new level. For instance, an acorn may have a mass of 2.034g, but the mass is not said to be ‘emergent.’ The mass of 2.034g is ‘resultant’ in that it is theoretically derivable given knowledge of the masses of each of the individual particles. An arguably ‘emergent’ property of the acorn is its ability to roll down a hill, or the fact that it can grow into a tree. These properties of the acorn are only “arguably” ‘emergent’ because it is conceivable that, for example, the roughly spherical shape of the acorn is deducible from properties of the atomic bonds of the acorn, and hence the rolling is also deducible. However, the specifics of this example are unimportant; the point is that in many cases, ‘emergence’ operates on a sliding scale where certain properties are *clearly not* ‘emergent,’ whereas others *really seem* to be ‘emergent.’ This is a very sloppy definition; mathematicians and philosophers have offered more rigorous criteria for the ‘emergence.’

1.1: The Mathematician’s Definition of ‘Emergence’

Mathematicians and physicists are trying hard to formalize a distinction between ‘resultant’ and ‘emergent,’ and they have developed mathematical tools that accurately characterize higher-level order. For instance, fractal geometry measures the irrational dimensionality of a system, thus providing insight into its relative level of complexity.² Similarly, other statistical techniques (e.g. mean field theory, renormalization group theory) give mathematically precise descriptions of high-level order in terms of the low-level components.³ These concepts allow for a mathematical evaluation of higher-level properties. However, such evaluative tools only describe higher-level order; they are not sufficient to determine whether the higher-level property should be deemed ‘emergent’ or ‘resultant.’

The concept of *self-organized criticality*, developed by Bak, Tang, and Wiesenfeld in 1989, has been suggested as a mathematical formulation more appropriate to defining ‘emergence.’ The precise mathematical definition of self-organized criticality

¹ C.f. Kauffman, 1995: 24.

² Mandelbrot, 1982

(SOC) is that the behavior in question must be describable by simple power laws,⁴ but the concept of SOC can be described without referring to equations. “Self-organization” here refers to the capacity of a system to exhibit spatial and temporal structures in the absence of forces external to the system.⁵ “Criticality” describes the extreme sensitivity and reactivity of the system. For example, water at 0°C is said to be ‘critical’ because an extremely small fluctuation in energy could cause the entire system to go through the phase transition to ice. Thus, self-organized criticality is the condition that a system can – without external influence – spontaneously exhibit general organization.

Self-organized criticality thus denotes a very specific type of order present in complex dynamical systems. Waldrop, Kauffman, and others suggest that SOC is a necessary criteria for emergence.⁶ This suggestion makes sense formally, in that any given system SOC is either present or absent. It is not a relative metric like fractal dimensionality, and it is therefore meaningful to ask if a system exhibits SOC. However, the leap from self-organized criticality to ‘emergent’ is not justified. The Boolean nature of SOC is convenient, and systems exhibiting SOC resemble systems thought to exhibit ‘emergent’ behavior, but this is not enough for us to redefine ‘emergence’ in terms of SOC. Or rather, ‘emergence’ could be defined as the presence of SOC, but the metaphysical implications of our current notion of ‘emergence’ will not necessarily apply in the redefinition.

The metaphysical inadequacy of a mathematical definition of ‘emergence’ extends beyond the specifics of self-organized criticality, it is a general shortcoming of any mathematical definition. Per Bak, the man who coined the term “self-organized criticality,” was clearly aware of this shortcoming:

A general theory of complexity must necessarily be *abstract*... At most, the theory can explain *why* there is variability, or what typical patterns may emerge, not what the particular outcome a particular system will be... the theory must be *statistical* and therefore cannot produce specific details.⁷

³ C.f. Nicols and Prigogine (1989), Dhar (1990), Jensen (1998)

⁴ Bak, Tang, and Wiesenfeld, 1987

⁵ C.f. Kohonen, 1995; Nicolis, 1989

⁶ C.f. Waldrop, 1992; Kauffman, 1996

⁷ Bak, 1996: 9-10

Thus, while mathematical formulation has provided general insight into the higher-order behavior of complex systems, only metaphysical arguments can determine the behavior's 'emergence.'

1.2: The Philosopher's Definition of Emergence

Unfortunately, philosophers have had only slightly better luck than the mathematicians in trying to rigorously define 'emergence,' and there is no universally accepted definition of the term.⁸ However, Jaewong Kim's criteria are generally accepted:

1. *Emergence of complex higher-level entities:* Systems with a higher-level of complexity emerge from the coming together of lower-level entities in new structural configurations.
2. *Emergence of higher-level properties:* All properties of higher-level entities arise out of the properties and relations that characterize their constituent parts.
3. *The unpredictability of emergent properties:* Emergent properties are not predictable from exhaustive information concerning their 'basal condition'.
4. *The unexplainability/irreducibility of emergent properties:* Emergent properties, unlike those that are merely resultant, are neither explainable nor reducible in terms of their basal conditions.
5. *The causal efficacy of the emergents:* Emergent properties have causal powers of their own – novel causal power irreducible to the causal powers of their basal components.⁹

⁸ C.f. Kim, 1999; Spencer-Smith, 1995; Stephan, 1992; Beckermann, 1992;

⁹ Kim, 1999: 20-22.

Kim's definition is fairly uncontroversial, though there has been some debate surrounding the principle of causal efficacy, also referred to as 'downward causation.' This principle states that once a property has been deemed emergent, it is free to influence its constituent parts. For instance, a rolling acorn moves its particles in a way that the particles cannot move themselves. Some philosophers, such as C. Lloyd Morgan, argue that downward causation, while often existing in the emergent property, should not be required for that property to be 'emergent.'¹⁰ This argument, however, appears to be a semantic one with no practical relevance. As Kim points out, "For what purpose would it serve to insist on the existence of emergent properties if they were mere epiphenomena with no causal or explanatory relevance?"¹¹ Thus, if the 'emergent' behavior is to be causally relevant, it must be free to affect its components.

2. Three Paradigmatic Examples

Before delving further into the emergentist debate, it will help to look at a few classic examples of inexplicable higher-level order. Fortunately, the world is filled with examples. For instance, an acorn's "tree potential" has little to do with the crystal structure of carbon, and even less to do with the exact positions of each carbon atom's 6 electrons; Newtonian dynamics are not derivable from quantum mechanics, and in general academic disciplines assume that laws applicable at one level of order are not always necessary to describe behavior at a higher level of complexity. The following instances of higher-level order are often cited in discussions of 'emergence:'

2.1: The (simplistic) Game "Life"

"The game is played on a two-dimensional grid as follows. On each square, there may or may not live an individual. A live individual is represented by a 1... the absence of an individual is represented by a 0. At each time step, the total number of live

¹⁰ Morgan, 1923: 25-34

¹¹ Kim, 1999: 19

individuals in the nine-cell neighborhood of a given cell is counted. If that number is greater than 3, the individual at that cell dies, presumably of over-crowding. If the number is 1 or 0, he will die of loneliness. A new individual is born on an empty square only if there are precisely three live neighbors.” Given these rules of propagation, the system is simulated on a computer for an indefinite period of time. Looking at the grid on the computer screen, each cell will blink on and off depending on the state of its neighbors. The patterns of blinking cells are quite amazing. In addition to simple periodic behavior, “a myriad of complicated structures can be constructed from these rules... There are configurations [called *gliders*] that propagate through the lattice... *Blinkers* shift back and forth between two states... [*glider guns*] produce gliders at a regular rate and send them off in the diagonal direction. There are even structures that bounce gliders back and forth.”¹²

2.2: Thermodynamics

Consider a mole of gas. “Under standard conditions, this amount of gas contains about 10^{24} particles... If we wish to describe the system in its microphysical details, that is, starting from the fundamentals of classical mechanics, then we must specify at a given time the position and velocity (or momentum) of each of the 10^{24} particles... However, there is a way out of this complexity. Instead of analyzing the microstate of the system... we can restrict the analysis to certain macrostates of the system... For example, instead of determining the velocity of each individual particle, one can consider the mean velocity of all particles of the distribution... Such considerations lead to certain macroscopic parameters like pressure and temperature, that is, to parameters that can be observed and measured directly... this form of abstraction is a legitimate and useful procedure to reduce the complexity of the system by reducing the complexity of its description.”¹³

¹² Bak, 1996: 108

¹³ Küppers, 1992: 244

2.3: Sand piles

“Consider a flat table, onto which sand is added slowly, one grain at a time... Initially, the grains of sand will stay more or less where they land. As we continue to add more sand, the pile becomes steeper, and small sand slides or avalanches occur... The addition of a single grain of sand can cause a local disturbance, but nothing dramatic happens to the pile... Eventually the slope reaches a certain value and cannot increase any further [and] there will occasionally be avalanches that span the whole pile.”¹⁴

Each of these examples contains higher-level order that presents a candidate ‘emergent’ property. In the game of life, the animated structures that ‘emerge’ from simple rules seem to be unpredictable based on the simple local rules of the system. Similarly, thermodynamics –a science that deals with temperatures and pressures – is a significant abstraction from the laws of particle physics and quantum mechanics that are said to determine the behavior of the gaseous particles. Finally, the avalanches that ‘emerge’ in the sandpile experiments seem unrelated to the properties of the grains themselves.

3. ‘Emergent’ vs. ‘Higher-Level Order’

For now, these examples are only intended to convey a rough idea of the type of behavior that is offhandedly referred to as ‘emergent.’ A more detailed analysis of these examples will follow, but before higher-level order can be deemed ‘emergent’ we must remedy a key shortcoming of Kim’s definition. Namely, Kim seems to imply that all inexplicable high-level order is ‘emergent.’ The fact that ‘emergence’ requires inexplicable high-level order does not mean that inexplicable high-level order is necessarily ‘emergent.’¹⁵ To claim that all inexplicable order is ‘emergent’ is no claim at all; rather, it is a way of couching the unknowable in scientific terms. For instance, the

¹⁴ Bak, 1996: 50-51

fact that an acorn is named “acorn” is a property of the whole that is surely not deducible from its constituents alone – the name “acorn” relies on a human that speaks English – but this undeducibility does not make the name ‘emergent.’ Nonetheless, the belief that ‘emergence’ is nothing more than a way of scientifically redefining uncertainty is fairly commonplace. Bernd-Olaf Küppers, for example, writes:

“biologists and associated philosophers of science have invented the concept of ‘emergence’ and the closely related concept of ‘downward causation’... in order to immunize themselves against the desperate picture of the world drawn by reductionism.”¹⁶

Per Bak has a similar interpretation:

“because of our inability to directly calculate how complex phenomena at one level arise from the physical mechanisms working at a deeper level, scientists sometimes throw up their hands and refer to these phenomena as ‘emergent’. They just pop out of nowhere.”¹⁷

Both philosophers are voicing the concern that ‘emergence’ has become almost synonymous with ‘unknowable.’ If ‘emergence’ is to mean anything of value, it must make a specific claim with regard to certain types of higher-level order. ‘Emergence’ intuitively reflects the irreducibility of the whole to its components; however, if this irreducibility can always be shown to be the result of a factor other than ‘emergence,’ then ‘emergence’ is not in, its own right, worth discussing. Hence, to validate the concept of ‘emergence’ there must be a type of higher-level order that cannot be explained *without* talking about ‘emergence.’

3.1: Prerequisites for emergence

¹⁵ In fairness to Kim, he implies the need for basal certainty in his criteria #3. However, this point is too important to be glossed over as it is in Kim (1999).

Notes

¹⁶ Küppers, 1992: 242

¹⁷ Bak, 1996: 6

There are two general types of systems where the unpredictability in the higher-level order can easily be explained without referring to ‘emergence:’ 1) Systems that are not ontologically reducible, 2) Systems that are not deterministic. Therefore, I propose that inexplicable higher-level behavior can only be called ‘emergent’ if the system meets the following criteria:

1) *Ontologically Reducible* - In a situation where domain **B** is constituted of components of domain **A**, ‘emergence’ refutes the claim that the factual laws and properties of **B** can be reduced to the laws and properties of **A**. In other words, ‘Emergence’ rejects the *epistemological* reduction of **B**’s properties to **A**, but it must assume the *ontological* reducibility. If **B** is composed of parts other than those from **A** (either from a third domain **C** or pulled out of the ether), then surely one cannot hope to account for **B**’s behavior solely in terms of **A**. One could not, in such a scenario, develop meaningful laws of ‘emergence’ that would systematically describe **B**’s behavior in terms of **A**, because there would not be a rigorous link between the two. At best, there could be an approximate connection, but this approximation would deteriorate in proportion to the amount of uncertainty in **B**. If ‘emergence’ does not require ontological reducibility, then proving the existence of ‘emergent’ behavior would be quite trivial.

In requiring ontological reducibility, we are effectively requiring that the system be isolated. The ‘emergent’ higher-level properties must come from within the system, not as a result of factors extrinsic to the system. An acorn has the name “acorn” because something external gave it that name; it cannot be regarded as an ‘emergent’ property of the acorn’s component molecules.

I should note that, in addition to assuming ontological reducibility, many proponents of emergence also presume the *material* ontological reduction of **B** to **A**.¹⁸ They believe behavior in **B** is only ‘emergent’ if **B** is composed of the physical elements of **A**. For example, Richard Spencer-Smith writes of emergence, “It is possible to conceive of entities as composed of *physical* constituents without commitment to the

¹⁸ C.f. McLaughlin, 1992:49; Kim, 1992:121-122

thesis that all facts about them must be explained in terms of these constituents.”¹⁹ However, the claim that **B** is composed of the *physical* elements of **A** is an assertion of non-reductive materialism, and is not required for **B**’s properties to be ‘emergent.’ While there is no evidence for immaterial basal components, their existence is not theoretically incompatible with ‘emergence.’ The basal components can be immaterial as long as the non-physical forces are completely understood, a requirement that is odd but sound.²⁰

2) *Deterministic* – In the same way that the high-level order in ontologically irreducible systems cannot be attributed to ‘emergence,’ the relevance of ‘emergence’ can never be known in systems that do not operate deterministically. In other words, if **A**’s components do not obey deterministic laws, a notion of ‘emergence’ is not necessary to show that **B** level properties are irreducible to **A**. In such a scenario there must be at least as much uncertainty at **B** as is produced by the randomness at **A**. Not even **A** would be explainable in terms of **A**; an epistemically transparent explanation of levels higher than **A** is clearly impossible.

4. Is ‘Emergence’ Real?

Higher-level order in systems that are ontologically irreducible or non-deterministic could potentially be ‘emergent’ but there is no way to prove that it is so. By requiring ontological reducibility and determinism we have restricted our analysis to systems where the higher-level order could only be irreducible if it were ‘emergent.’ In such systems all the laws and properties of **A** are known and understood; the only obstacle to a reduction of **B** to **A** is some form of ‘emergence.’

4.1: A Note on Generalization

¹⁹ Spencer-Smith, 1995:116 italics added

²⁰ It seems that this line of reasoning – that emergence can exist in conjunction with immaterial components – is self-defeating, or at least redundant. If one believes that higher-level objects can be composed of

The task, then, is to find an ontologically reducible, deterministic (ORD) system, and find out whether it has irreducible high-level order. If irreducible order is found in such a system, ‘emergence’ can stand as a meaningful theory; however, if all higher-level order in such systems turns out to be reducible, then ‘emergence’ is effectively useless. This inductive inference of the validity of ‘emergence’ is necessary because a general proof of emergence in all complex systems is too much to ask; to do so would require proving the generic unknowability of a general type of knowledge. While such a feat may be feasible, it is beyond the scope of this paper. The weakness of inductive proofs notwithstanding, if ‘emergence’ can be shown to exist in a single system, then epistemological reductionism cannot be universally true. Conversely, if ‘emergence’ cannot be shown to exist in at least one system, then there is no proof of its existence. Moreover, if a specific property that is generally considered ‘emergent’ can be shown to be reducibly resultant, then other ‘emergent’ properties might really be resultant as well. Or, at the very least, there is no evidence – aside from the qualitative – to suggest the next system is any different,²¹ and the disproof of one paradigmatically ‘emergent’ property implies the fallacy of the next. Perhaps the next system would more complex and therefore more difficult to reduce, but there is no theoretical obstacle to its reduction.

4.2: ‘Emergence’ in Thermodynamics and Sand Piles

The theoretical version of the thermodynamics scenario is an example of an ORD system. Physicists have formulated a set of laws at the (lower) level of classical and quantum mechanics; likewise they have separately formulated laws at the (higher) level of thermodynamic equilibrium systems. In the theoretical realm, the higher-level system is ontologically reducible to its constituent particles, and each particle interaction is governed by classical deterministic rules. Here we have level **A** of statistical mechanics, and level **B** of thermodynamics. In this instance, it turns out, it is possible to deduce the laws of **B** from those of **A**. There is no theoretical obstacle to the derivation of

unknowable components at the level below, then emergence is beside the point. The unpredictability exists by virtue of the immaterial, not because of emergence.

²¹ I will deal with the influence of “environment” in section IV

macrostate behavior from microstate properties.²² The mathematical proof is obscene, but one can deduce the ideal gas law $PV=nKT$ from the laws governing the classical behavior of particles. “Heat” is really just a function of the amount of information that is not known about the energy states of the particles. In other words, given a precise specification of the boundary conditions of the particles, you can theoretically derive the temperature and pressure of the system. As Bernd-Olaf Küppers writes, “although the Schrödinger equation cannot be solved for complex molecules... chemistry can be reduced in principle completely to the laws of quantum physics.”²³

In the world of mathematics, then, we have an example of seemingly ‘emergent’ behavior that can be shown to be resultant. However, the emergentist could point out a fundamental caveat in the thermodynamics example: The reduction does not hold in the experimental analysis of real systems, it only works in the theoretical realm. Experimental reducibility fails for reasons of quantum uncertainty and chaos. Briefly, the Uncertainty principle, a basic principle of classical and quantum mechanics, states that one can never know the exact position and velocity of a single particle. In chaotic systems, an arbitrarily small amount of uncertainty can lead to extremely large discrepancies later on. A consequence of this quantum chaos is that, even given the exact position of a particle, one can never know its subsequent position. Predictive accuracy decreases exponentially as the time interval is increased, and it becomes impossible to get from **A** to **B**. For the derivation to hold, it can only occur in the theoretical realm of equations and variables. It can’t be experimentally demonstrated and thus no practical claims about emergence can be made.

Though it is true that in practice the macroscopic thermal behavior cannot be derived from particle behavior, this does not make the macroscopic behavior ‘emergent.’ This should be evident in consideration of the earlier discussion regarding the need for ontological reducibility and determinism. Particles, on a fundamental level, do not behave deterministically. Physicists argue over the relevance of such uncertainty, and most agree that quantum effects entirely cancel out on larger scales, but even if this were the case the chaotic behavior renders any determinism unknowable. So whether or not

²² C.f. Schroeder, 2000:Introduction; Nagel,1961:338-345

²³ Küppers, 1992: 244

determinism is theoretically present, it is experimentally undetectable. Thus, even if a reduction were in fact possible, we would never know. Not only is it impossible to get from **A** to **B**, it is impossible to get from a current state of **A** to a future state of **A**. In such a scenario we cannot call the unpredictable behavior ‘emergent’ because it can be disregarded as the result of uncertain elements in the basal conditions. As the physicist Henrik Jensen writes, “The mathematical complexity can be prohibitive.”²⁴

Unfortunately, most real systems are subject to similar quantum uncertainty. Requiring determinism appeared benign enough at first, but if the claims of quantum theory are taken to their logical extreme, determinism may be too much to ask of any system in the natural world. The sand pile is conceptually no better than thermodynamics. As is the case in particle physics, no meaningful conclusions about the sand pile’s ‘emergence’ can be drawn because any behavior deemed ‘emergent’ could be the result of our incomplete knowledge of the initial positions and subsequent behavior of the system’s particles. Uncertainty and chaos preclude the conclusion of ‘emergence’ in the physical realm.

4.3: ‘Emergence’ in the Game “Life”

To examine ‘emergence’, then, we need a system that is not affected by quantum chaos. The game “Life” is such a system because it exists in the computational world. Here the person running the simulation specifies the initial conditions and all rules of behavior. The basal conditions of **A** are guaranteed by the ORD nature of the system; therefore it is meaningful to call irreducible higher-level order ‘emergent.’ This is not to say that the higher-level order is necessarily ‘emergent’ – the behavior first must be shown to fit the criteria required of an ‘emergent’ property. However, if the **B**-level properties in the game “Life” do fit Kim’s criteria, then the properties truly are ‘emergent.’ In all the other systems the case was such that even if the **B**-level properties fit the criteria for ‘emergent,’ the properties would not necessarily be the result of

²⁴ Jensen, 1998: 77

‘emergence,’ because they could have been the result of something else. The game “Life,” on the other hand, could potentially justify a theory of ‘emergence.’

Are the ‘emergent’ **B**-level phenomena (blinkers, gliders, reflectors, etc) in the game “Life” fundamentally novel, i.e. do they meet the criteria as specified by Kim? The first two criteria can only be satisfied qualitatively, and in the case of the “Life” this is easily done: The structural configurations of **B** obey laws of a higher level of complexity than the rules of automata governing **A** (criteria 1), and the higher-level entities at **B** are produced by their constituent parts (criteria 2). The controversial issues in the game “Life” are the third and fourth criteria - the ones regarding the predictability, explicability, reducibility, and deducibility of the emergent phenomena. The fifth criteria, that of downward causation, is only relevant if these first two are filled.

The third criteria, that “emergent properties are not predictable from exhaustive information concerning their ‘basal condition,’” is *not* satisfied. **B**-level order in “Life” is predictable. This predictability exists in two slightly different forms: inductive/inferential predictability, and computational predictability. *Inductive predictability* is the principle that if higher-level phenomena **B’** occur once with the lower-level conditions **A’**, then **B’** is guaranteed to occur any other time **A’** is present. In the game “Life” the phenomena are inductively predictable because a given set of basal conditions can produce only one higher-level behavior. Inductive predictability is not generally regarded as “true” predictability because it is a correlative – not a causal – property. The fact that **A’** occurs concurrently with **B’** does not mean **B’** was derived from **A’**. In fact Lewes, one of the first emergentists, believed that the inability to proceed beyond inductive deducibility was the hallmark of ‘emergence.’ In his words, “the nature of emergent characters can only be learnt by experience of their occurrence; hence they are unpredictable before the event.”²⁵

I will not dwell any further on the importance of inductive predictability, because it is much less important than the computational predictability that is also present. *Computational predictability* is the property that future states of high-level order can be derived by running the simulation ahead of time. Unlike inductive predictability, computational predictability guarantees the causal role of **A’** in determining **B’**. Looking

²⁵ Morgan, 1923: 5

beyond the game “Life,” computational deducibility must exist in any ORD system that, not just computationally simulated ones. Even chaotic (extreme sensitivity to initial conditions) and critical/contingent (extreme reactivity) systems can be computationally predicted given the boundary conditions.²⁶ As long as positions can be exactly specified at one temporal point, and the deterministic laws can be formalized (as is the case in ORD systems), all future states can (in theory!) be computationally deduced.²⁷

Since all global behavior in “Life” (and any formal system) is determined by, and predictable from, local low-level rules, such systems fail to meet Kim’s fifth criteria of causal efficacy (i.e. downward causation). The behavior of the system is determined and effected entirely through rules governing the parts. Though blinkers and gliders can be understood at a higher-level, and their behavior can be described formally, the higher-level phenomena exert no causal influence in their own right. It is tempting to interpret the behavior of level **B** as autonomous, but such an interpretation attributes more than the formal nature of the system permits.

ORD systems meet Kim’s first and second criteria, but fall short of the third and fifth criteria. The fourth criteria, that the emergent phenomena be explainable in terms of the basal conditions, is much trickier to evaluate. The ambiguity exists because different people have different criteria for what it means to explain something. On one extreme, predictive certainty alone could be regarded as a legitimate form of explanation; on the other side of the spectrum, an epistemically transparent explanation might be required. The game “Life” clearly satisfies the former but not the latter, i.e. computational predictability is provably obtainable, but such prediction is not an epistemically transparent explanation of why particular local rules produce the observed global behavior.

In the end, the validity of ‘emergence’ largely depends on the subjective definition of “explanation.” For the purposes of this paper, I will define ‘adequate explanation’ as mathematical deducibility of the form obtained in the derivation of the ideal gas law from the laws of statistical mechanics. This definition requires a mathematical understanding of the system beyond prediction, but avoids the hopelessly

²⁶ Bak, 1996: 105-113

²⁷ C.f. Von Neumann, 1961; Turing, 194?

subjective description of “what it means to understand something.” In the game “Life,” high-level order is mathematically deducible *sometimes*. In certain configurations general characteristics of the macroscopic behavior can be derived and abstracted in the same way temperature was extracted from statistical mechanics.²⁸ However, such derivation can only occur in a mathematically *critical* configuration of the basal components; although it has not been ruled out, general mathematical abstraction has yet to be achieved.²⁹ ‘Emergence’ in the game “Life” has not been ruled out, but it stands on very thin ice.

4.4: Is ‘Emergence’ Real?

Taking a step back, it may not be clear whether a general theory ‘emergence’ has been refuted or defended. Within the theoretical framework that physicists have used to describe the physical world, emergence can be convincingly refuted. In the physical world an experimental demonstration of ‘emergence’ is doomed to fail because of the uncertainty surrounding the basal components of nature. In ORD systems where higher-level order could only be considered ‘emergent,’ such behavior will be predictable, but not always explainable.

‘Emergent’ behavior, if it is said to exist, will be severely limited by the fact that it cannot affect anything in a practical sense. While it is not always clear how **A** produces **B**, **B**’s behavior is always reducible to and predictable from knowledge of **A**. Whether or not one calls this form of reduction “epistemological” is not the issue – we at least have a “for all practical purposes” reduction. This is not to say that the lack of explicability is insignificant, on the contrary it seems fair to conclude that ‘emergence’ is precisely the reason for epistemic opacity in ORD systems. However, ‘emergence’ is at most a passive way of describing our inability to see why the whole acts in ways seemingly unrelated to its parts. ‘Emergent’ behavior has no autonomous causal efficacy.

²⁸ Gardner, 1970

²⁹ C.f. Wolfram, 1994

5. Conclusions

5.1: Synopsis

Given higher-level order **B** in a system **S** that is irreducible to the basal components **A**, the line of argument of this essay has been as follows:

- 1) 'Emergence' is poorly defined; For lack of a better definition, **B** can only be considered 'emergent' if Kim's criteria are satisfied .
- 2) If **S** is not both ontologically reducible and deterministic (ORD), irreducible order in **B** could be the result of something other than emergence.
- 3) Even given satisfaction of Kim's criteria, **B** cannot be known to be 'emergent' unless **S** is an ORD system.
- 4) In theoretical thermodynamics, an ORD system, **B** is predictable and mathematically reducible/deducible.
- 5) In the game "Life," an ORD system, **B** is predictable. **B** is not generally mathematically deducible in "Life."
- 6) For ORD systems in general, 'emergence' exerts no causal role; at most it refers to a specific type of epistemological opacity.
- 7) For any system, the autonomous causal efficacy of 'emergent' behavior not provable.

One could conceivably argue against most of the preceding claims and it is worth looking at possible dissensions:

Claim (1) is relatively benign, although one could argue that a different set of criteria are better markers for 'emergence,' However, the specifics of Kim's definition aren't as important as identifying the key characteristics of emergent behavior: unpredictability, undeducibility, irreducibility, and unexplainability. By arguing that an unrelated property could cause **B** to be 'emergent,' one could opt out of the conclusions that follow.

Claim (2) is argued extensively in section 3, and seems irrefutable.

Claim (3) is the logical result of (1) and (2), and cannot be argued directly.

Claim (4) is a mathematical fact.

Claim (5) is also mathematically provable. A conceivable dissent could be made on the grounds that computational and inductive predictability are insufficient to justify the claim general predictability. However, to attribute more to “predictability” than the “the ability to predict” is to attribute an explanatory meaning to the term. This essay does not attempt to refute the explanatory validity of ‘emergence.’

Claim (6) is admittedly weak. It relies on the validity of inferring from instances to the whole, a generally invalid conclusion. However, in discussing ‘emergence,’ there is really no alternative; section 4.1 addresses this issue. The refutation of ‘emergence’ must be done on a casewise basis – the emergentist must propose that **B** is ‘emergent’ before the reductionist can refute the claim. In claim (5) I am essentially shifting the burden of proof onto the emergentist: The claims made here are valid until a counterexample is offered.

Claim (7) is the logical result of (3) and (6). I will, however, point out that one could contest the way I have implied that claims made in the theoretical world are applicable in the world of nature. This implication is invalid, for example, if one asserts some variation of divine influence, or argues that all objects of the world are not composed of a finite number of fundamental substances. These dissensions are formally legitimate and will not be discussed here.

5.2: Conclusion

‘Emergence’ cannot be shown to be more than a specific explanatory barrier between components **A** and their formations **B**. Current discussions of ‘emergence,’ both within the literature and in general, overestimate the role of ‘emergent’ behavior. Horst has it right when he writes:

If a property M supervenes upon P, but the P-to-M connection is epistemically opaque, M is said to be **emergent** from P. That is, *emergence* equals supervenience plus cognitive impenetrability.

An attribution of downward causality is unjustifiable, as is any assertion of the autonomy of the **B**-level properties. The whole may appear to be more than the sum of its parts, but it – and its behavior – is entirely determined by its parts.

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