10

Brute Facts about Emergence

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1. Introduction

If there are emergent properties then some of their features must be accepted as brute facts. However, brute facts are violations of the Principle of Sufficient Reason (PSR). The PSR states that everything that is the case has an explanation and that every contingently true proposition is true for some reason (Pruss 2006: 3).

Emergentists are committed to the idea that at some points over the course of natural history, genuinely novel properties come into existence. On their view, being genuinely novel means that these properties are not entirely explainable in terms of what preceded them. Thus, emergent properties are brute with respect to the prior constituents of the universe.

Emergentism assumes that there are genuinely (not merely apparently) diverse kinds of things in nature and that this diversity can increase through time. In addition to defending this assumption, the goal of emergentism is to provide a theory that correctly characterizes novelty and diversity. Given these goals, given the central place of bruteness, and given the accompanying violation of the PSR, emergentism can easily appear anti-scientific, unphilosophical, or even irrational.

Historically, the connection between brute facts and emergence was noted repeatedly in the short life of a philosophical movement that Brian McLaughlin dubbed "British Emergentism" (1992). The central figures in this movement—Samuel Alexander, C. D. Broad, and Lloyd Morgan—published their most important work in the 1920s. Following its brief efflorescence, the influence of British Emergentism declined dramatically in the 1930s. This decline was due to a variety of factors but prominent among them was the sense that emergentism was an anti-scientific movement.

In hindsight the emergentists were unable to convince their critics of the plausibility of their view for obvious reasons. In the face of developments in physics and biology from the 1930s to the present day the emergentists' examples and argumentative strategies were completely unpersuasive. Philosophers were convinced by the progress of the sciences that a reductive research agenda offered the most fruitful approach to reality. They struggled, of course, to understand the place of minds, values, meaning, and mathematics in this physicalist framework. A large part of philosophical practice from the 1950s until relatively recently has involved reconciling aspects of human experience and nature that did not *seem* straightforwardly physical with the view that ultimately everything *is* physical. From the perspective of philosophers who struggled to reconcile what Sellars called the scientific image and the manifest image, emergentism was at best orthogonal to their project, and at worst it seemed confused or uninformed.

Emergentism remained a marginal historical curiosity that garnered little serious consideration from philosophers until about the mid1990s. While philosophers in the 1990s were revisiting emergence as a possible alternative to physicalism, powerful lines of criticism against emergence also reappeared. As we shall see, in these debates the bruteness of emergence bumps against a physicalist commitment to a version of the PSR. I will argue that, contrary to physicalist critiques of emergentism, there are several ways of understanding the bruteness of emergence that are compatible with scientific rationality. One consequence of this argument is that being compatible with scientific rationality does not necessarily mean that a philosophical position is compatible with physicalism. Furthermore, on the view presented here, scientific rationality is compatible with the denial of some versions of the PSR.

Sometimes brute facts are thought of as propositions rather than phenomena or states of affairs.[1] Cast in terms of contingently true propositions, PSR is not a widely held metaphysical principle and there are a variety of good reasons to reject its metaphysically stronger forms. The most influential of these is Van Inwagen's argument that the PSR collapses the distinction between necessity and possibility (Van Inwagen 1983). This circumstance is known as modal fatalism. If the PSR is true then all truths are necessary. (See also Hudson 1997.) Modal fatalism is widely regarded as an unacceptable commitment. If the PSR leads there, then most contemporary metaphysicians think that it has to be wrong.

It turns out that those aspects of the PSR that are most appealing to common sense can be saved in a straightforward manner without committing us to anti-emergentism, modal fatalism, or any other metaphysical consequences. In other words, we can continue to hold aspects of the PSR that are important for scientific rationality independently of whether we accept or deny the PSR as a metaphysical principle. The PSR can be understood as either a methodological heuristic for scientific inquiry or as a metaphysical principle governing Being. I suggest that one can coherently reject the latter while endorsing the former.

Given the well-known shortcomings of physicalism and a more relaxed version of the PSR, the plausibility of emergentism increases significantly.

[1] Doing so allows philosophers to be clearer about the kinds of facts that would not count as brute. Brute facts, they say, are *contingently true propositions* that do not have an explanation. Propositions that are true of necessity are not what philosophers mean by brute facts even if those propositions do not have an explanation or cause.

2. The Role of Brute Facts in British Emergentism

The British Emergentists held a view of the fundamental nature of the universe that was informed by the physics of their day. Like non-reductive physicalists of more recent decades, they sought to reconcile the generality and fundamentality of physics with the apparent reality of emergent phenomena. On their view, novel domains of reality emerge from matter. These novel domains *depend on* matter in some respects but are independent of matter in others. There could be no chemistry without physics, but they contended that the laws of chemistry simply cannot be reduced to or predicted from the laws of physics. On the emergentist view there are brute facts about chemistry that mark it as constituting an ontologically novel set of properties.

While the British Emergentists were not a unified bloc, they all regarded history as punctuated by the appearance of genuine novelties. If there are emergent properties, they thought, then there is nothing about the laws governing the material world or the properties of the basic physical stuff that would allow an ideal epistemic agent (what Broad called a mathematical archangel) to predict them ahead of time. Broad mentioned the smell of a chemical compound as one of the properties that the archangel would have been unable to predict (1923: 71). A contemporary emergentist would choose a different example, arguing for instance that knowing the complete theory governing the atomic and elemental level of reality does not allow chemists to derive a complete theory that governs valence and bonding (Scerri 1994, 1997). And yet it is a historical fact that these novel chemical domains somehow arose out of physics. Notice here that the novelty of emergent properties relative to what came before, is an objective matter. It is not simply a matter of *our* finding them surprising or being unable to predict them, instead according to the emergentists there is an objective difference in kind between the emergent property and what preceded it.

Chemistry is important for Alexander, Broad, and Morgan because its emergence from physics indicates the first appearance of a non-material "order of existent" with its own laws. Other, higher-level emergent properties like those associated with biology and psychology result from complexes of these (and other) distinct orders of existents. Thus, Alexander described properties associated with living things as being the result of the complex interplay of physical and chemical properties. This is what he meant by calling life a physical chemical complex in his 1916–18 Gifford Lectures (later published in his *Space, Time, and Deity*, 1920).[2] Once this difference between the physical and non-physical order of existents is established, they assumed that the brute facts

[2] "[L]et me take a few examples. Material things have certain motions of their own which carry the quality of materials. In the presence of light they are endowed with the secondary quality of colour. Physical and chemical processes of a certain complexity have the quality of life. The new quality emerges with this constellation of such processes, and therefore life is at once a physical chemical complex and is not merely physical and chemical, for these terms do not sufficiently characterize the new complex which in the course and order of time has been generated out of them" (Alexander 1920: 46–7).

concerning other, higher-level emergent properties would be understood as resulting in the same manner from constellations of preceding levels.

Another reason for concentrating on the emergence of chemistry, as opposed, for example, to consciousness, was that in the chemical case it is possible to reflect on how an order of existents can genuinely differ from physics in a way that does not invoke aspects of human subjectivity. For the emergentists, qualitative experience would be an obvious case of a domain that differs from the physical, but chemistry allows the emergentists to talk about the non-physical without falling into what they would have regarded as the traps of vitalism or spiritualism.

If there are genuine differences then, on the emergentist view, they must be accepted as brute facts about the natural world. We have reason to believe that chemical properties are not reducible to physics, they argue, but these reasons are not arrived at via a priori reasoning. Broad was especially sensitive to the empirical nature of a claim about the bruteness of chemical facts. Chemical facts appear to be brute, but the logical possibility that they might be reducible cannot be eliminated. Thus, Broad comments on Alexander's characterization of emergence as follows:

> It was held that the characteristic differences between the behavior of Oxygen and Hydrogen are due in no way to differences of structure or components, but must simply be accepted as ultimate facts. This first alternative can hardly be counted as one way of *explaining* differences of behavior, since it consists in holding that there are certain differences which cannot be explained, even in part, but must simply be swallowed whole with that philosophic jam which Professor Alexander calls "natural piety". *It is worthwhile to remark that we could never be logically compelled to hold this view* [...] Nevertheless, it is perfectly possible that [...] there are certain ultimate differences in the material world which must just be accepted as brute facts.
>
> (Broad 1923: 55, emphasis mine)

The passage from Samuel Alexander's *Space, Time, and Deity* to which Broad's comments are addressed is well known and frequently cited. It is worth reproducing here since it presents the way that Alexander understood the connection between the limits of explanation and the emergence of higher qualities from lower levels of existence:

> The higher quality emerges from the lower level of existence and has its roots therein, but it emerges therefrom, and it does not belong to that level, but constitutes in its possessor a new order of existent with its special laws of behaviour. The existence of emergent qualities thus described is something to be noted, as some would say, under the compulsion of brute empirical fact, or, as I should prefer to say in less harsh terms, to be accepted with the "natural piety" of the investigator. It admits no explanation. (Alexander 1920: 46–7)

While there are aspects of his metaphysics that are difficult to accept, nothing about his views of emergence and explanation should strike contemporary philosophers as particularly alien.[3] One familiar aspect of Alexander's characterization of brute facts here

[3] Alexander's metaphysics has some features that are speculative and exotic. Perhaps the most difficult for mainstream philosophers to read sympathetically in 2016 is his idea that the universe is developing in a direction determined by an as yet unactualized deity.

is his emphasis on their empirical nature. By 'empirical' Alexander means "nothing more than the method used in the special sciences. It is a description of method and not of the subject matter and is equivalent to the experiential" (1920: 4). On his view, both philosophy and science should be grounded in the empirical. Philosophy, as he understood it, "differs from the sciences nowise in its spirit but only in its boundaries [...] its method will be like theirs empirical" (1920: 4). In this respect, there is a naturalistic feel to Alexander's view of philosophy. Elsewhere, for example, he argues that finite minds are not privileged aspects of what he calls "the democracy of things" and that "the problem of knowledge, the subject matter of epistemology, is nothing but a chapter, though an important one, in the wider science of metaphysics, and not its indispensable foundation" (1920: 7).

Alexander's view of brute facts should be understood in the context of his philosophical methodology. We are *compelled* by empirical reality, he thought, to acknowledge the existence of emergent properties. The evidence of our best science leads us to conclude that chemistry, for example, constitutes a "new order of existent." This is not the picture of nature that Alexander preferred. It is striking that he is a reluctant emergentist whose self-described philosophical disposition is to resist appeals to unexplained differences in explanation. Alexander, like most philosophers, is motivated by the spirit of the PSR and is inclined to avoid acknowledging brute facts entirely: "I confess to feeling, as a metaphysician, a horror of notions which the mind takes for ultimate and undefinable" (1920: xxiv). In this sense, the philosophical impulse pushes for explanations that do not appeal to brute facts. By contrast the special sciences, by revealing differences among kinds of beings, impose empirical constraints that he recommends we acknowledge with Wordsworthian natural piety.[4]

Alexander and Broad acknowledge the possibility that apparent differences are illusory and can be explained away with the progress of inquiry. Broad discusses the conditions that would need to obtain in order for what he calls the Ideal of Pure Mechanism to be realized at great length. He concludes that it is highly unlikely that the diversity of qualities in the material world can ever be given the kind of reductive mechanistic treatment that he associates with Mechanism but he is fully aware that this conclusion rests on a posteriori considerations. For Broad the central question is: "Are the apparently different kinds of material objects irreducibly different?" He admits that he remains uncertain "that the question can ever be settled conclusively" (Broad 1923: 43).

[4] Alexander's reference to Wordsworth is worth unpacking. In "My Heart Leaps Up" the poet is expressing the wish that his days could be bound together by natural piety. Natural piety is the term he uses for the feeling he has in the moment that he sees a rainbow; the moment when his "heart leaps up." The poet and Alexander undoubtedly recognize that the rainbow is a symbolically loaded phenomenon for the enlightenment project. Explanations of rainbows in terms of the science of optics had subversive significance given the religious meaning of rainbows as marks of the covenant with God. Nevertheless, the poet's experience in the presence of the rainbow is an involuntary reaction to the impressive fact of the rainbow itself independently of its religious significance or its scientific explanation. It is natural piety that the poet feels, as opposed to a religious sentiment. Alexander's use of the phrase marks his view that emergent properties simply force themselves on us, in spite of our commitment to the PSR.

Thus, both Broad and Alexander are moved to embrace emergentism by the facts as they find them. They take as starting points two relatively uncontroversial positions. Broad asserts that "it is perfectly possible that [. . .] there are certain ultimate differences in the material world which must just be accepted as brute facts." Alexander suggests that empirical facts (and not metaphysical or strictly logical arguments) compel us to acknowledge emergent properties. Given these assumptions, emergentism seems to be the view that reductionism is not necessarily true and that it is more plausible to believe that there are, to use Broad's language, irreducibly different kinds of material objects. As we will see below, most contemporary versions of physicalism are also argued for in an a posteriori manner. In fact, since physicalism relies, in part, on the results of an empirical science for its ontological commitments, it would be difficult to coherently regard physicalism as being true a priori. Thus, the central difference between physicalists and emergentists is not their commitment to scientific inquiry or empirical evidence more generally. Instead, they differ with respect to the plausibility of some version of what Broad calls the Ideal of Pure Mechanism. This ideal is an important cousin of the PSR as we will explain in more detail below.

Alexander and Broad argued as though emergentism was forced upon us by empirical evidence. In some sense, their view of emergence begins from our commonsense recognition that nature is divided into distinct levels or kinds. The weakness of such views is the assumption that we can reliably discern these differences. Most obviously, arguments for emergence that rely on specific examples are vulnerable to being defeated by the progress of science. We have a number of prominent examples in the history of science in which it was discovered that common sense misled us and that apparently distinct kinds of objects or properties simply are not distinct in the way that we had supposed. For example, electricity and magnetism are now understood to be manifestations of the same underlying electromagnetic field. While common sense might have encouraged us to believe that electricity and magnetism are distinct kinds, we came to recognize the unity underlying the apparent difference.

The history of science did not turn out quite as the British Emergentists had anticipated. Brian McLaughlin writes: "On the current evidence, the main doctrines of British Emergentism seem 'kooky'" (1992: 55). The most important evidence that McLaughlin cites against emergentism is an interpretation of the Schrödinger wave equation in which it applies with maximal generality to all dynamical systems. Published in 1926, shortly after the British Emergentists had published their most important works, Erwin Schrödinger's equation is the foundation of nonrelativistic quantum mechanics. It presents a law governing the values of states of quantum mechanical systems in the future. Insofar as there is anything distinctive about emergent properties, those distinctive properties cannot make a difference to the atomic and subatomic constituents that has not previously been accounted for by the Schrödinger equation.

Given a physicalist perspective on ontology and individuation if properties make no quantum mechanical difference, then they can be dismissed as, at best, epiphenomenal. The central charge against emergentism is that it prematurely embraced specific limits to scientific explanation and that it takes those limits to license unwarranted metaphysical claims. Historically, the British Emergentists' assumption that physics was limited was regarded by many critics to have been superseded by the generality (and completeness) of the Schrödinger equation and by the resulting reduction of chemistry to physics.

The British Emergentists did not present a clear defense of their view of the limits to explanation independently of citing specific cases where they regarded reductive explanation as inadequate. Because of the central role of examples in their accounts, they appeared to be making bets against the prospects of a successful reduction of chemistry to physics based on common sense and experiential evidence rather than making a more general point about the limits of explanation.

As we saw above, Broad and Alexander draw examples of emergent properties from chemistry. They assumed (echoing Mill's earlier arguments to the same effect) that chemical phenomena constitute a level of reality that is, in some sense, independent from the laws of physics. The idea of an independent kind of law, what Mill calls a heteropathic law, derives from his discussion of the limits of mechanical laws in his *A System of Logic* (1843). The influence of laws of the same kind can be summed together in a manner similar to vector addition in mechanics. By contrast, heteropathic laws admit no such addition. O'Connor and Wong describe Mill's view of mechanical explanation as follows: "the essence of the mechanical mode is that the total effect of several causes acting in concert is identical to what would have been the sum of effects of each of the causes acting alone. The laws of vector addition of forces, such as the parallelogram law, are for him the paradigm example of the conjoint action of causes in the mechanical mode" (2015). For Mill, combinations of chemical causes did not permit this kind of straightforward summing and therefore, on his view, the chemical level is not amenable to mechanical explanation.

The difference between Mill's time and our own is that today physicists and perhaps the majority of chemists simply assume that chemistry can be explained in quantum mechanical terms. It is worth noting that we have a more precise understanding of the explanatory limits of physics with respect to chemistry today than ever before. Mill's account is less appealing given the apparent reduction of chemistry to quantum mechanics made possible by Schrödinger. However, contrary to the reductionist consensus, there is a range of arguments to the effect that chemistry is not reducible to quantum physics. Robin Hendry (2010) for example explains that some chemically relevant structural properties cannot be accounted for by current physics. Weisberg, Needham, and Hendry (2011) emphasize, in particular, the problematic status of isomers for reductionists. Isomers are molecules with the same kinds and numbers of atoms, but with different molecular structures. They give the example of methyl ether and ethanol, which share a Hamiltonian but exhibit very different chemical behavior.[5] Given the Schrödinger equation alone, the structural differences

[5] "Ethanol is extremely soluble in water, whereas dimethyl ether is only partially soluble in water. Ethanol boils at 78.4°C, while dimethyl ether boils at 34.6°C. Drinking ethanol leads to intoxication, while drinking dimethyl ether has no such effect" (Weisberg, Needham, and Hendry 2011).

between methyl ether and ethanol are not represented quantum mechanically. Since this structural difference is the basis for a difference in chemical properties, and since that structural difference is not derivable from quantum mechanics, Hendry and others conclude that chemical properties are not reducible to quantum mechanical properties (Scerri1997; Hendry 2010).

Some core chemical notions remain difficult to reduce contrary to the consensus view that chemistry has been reduced to physics. The consensus view is supported by the fact that the behavior of anionic hydrogen is explainable precisely in quantum mechanical terms and from the reductionist perspective, more complex chemical properties will be reducible in a manner that simply follows from the reduction of hydrogen.

The impressive conceptual achievement marked by the reduction of hydrogen to quantum mechanics means that the anti-reductionist position cannot be regarded as self-evidently true. In other words, what Alexander took to be evidence for the irreducibility of chemistry can no longer be regarded as compelling. Rather than being forced by common sense and empirical evidence into accepting that chemical and physical properties are of different kinds, the question of whether chemistry has been successfully reduced to physics has become a philosophical question.

Can empirical evidence provide compelling reason to judge any property as being emergent in the first place? While there are good arguments for at least some chemical properties being emergent, these arguments are not "experiential," to use Alexander's term. Contemporary arguments for the bruteness of chemical properties with respect to physics, for example the argument from isomers, are located within the context of highly theoretical reasoning mediated by a great deal of scientific inquiry. While the British Emergentists correctly identified emergent properties as brute, their reasons for believing those properties to be brute were not persuasive.

3. Brute Facts about Weak Emergence

Mindful of its origins, philosophers are sometimes perplexed by the use of the term 'emergence' in contemporary science.[6] One of the principal complaints against 'emergence' is that it is unclear and that the term has a variety of divergent meanings. In one sense, this charge is unfair and the concept of emergence is perfectly straightforward and clear: A property counts as emergent insofar as it is *novel* and *real* relative to its basal properties. The complaint has merit since disagreements concerning what we mean by novel, what we mean by real, and what we regard as the relevant basal or fundamental properties make the meaningful discussions of the concept of emergence murky. Adjudicating philosophical disagreements about emergence is difficult because

[6] Bedau and Humphreys describe emergence as "one of the liveliest areas of research in both science and philosophy" (2008: i). Nobel laureate Robert Laughlin hails the dawning of the Age of Emergence in physics (2005).

of differences concerning related metaphysical notions, such as the question of what counts as more basic and more fundamental.

One way to answer the question of whether there are emergent properties would be to settle on a satisfactory account of fundamentality. However, prospects for consensus here are not bright. This might be due to the fact that competing accounts of fundamentality are compatible with our best scientific picture of the world. In order for us to find traction and common ground it will be useful to bracket the question of which account of the fundamental level we favor. By focusing on brute facts about emergence we address the problem of emergence directly rather than siding with one or another fundamental account. We can ask one question concerning the nature of the fundamentality that is directly relevant to the problem of emergence, namely whether accounts of the fundamental level can be complete in the relevant ways. This is a big question, but not an intractable one. It also relates to logical or conceptual problems that do not necessarily require a posteriori evidence to solve.

As we shall see, the bruteness of what are known as weakly emergent properties is virtually indisputable. This bruteness is a straightforwardly conceptual or mathematical matter. So, in at least one respect we can show that the fundamental level will be incomplete. The question is, does the kind of bruteness that we find in weakly emergent properties have any philosophical relevance in broader debates about the legitimacy of emergence? There are clearly going to be brute facts that have no bearing on, for example, the question of whether we accept the Principle of Sufficient Reason or whether we think that there are facts about causal powers of emergent properties that are not captured by physicalism.

Before turning to the question of the bruteness of weak emergence, we must first tackle the varying ways that a property can relate to the more fundamental or basic level. Often, in discussions of emergence, this relation is understood to be at least partly mediated by the participation of an epistemic agent. More metaphysically robust versions of emergence, so-called strong emergence, focus on a relation between strongly emergent properties and the basal properties that is independent of any agent.

Let's begin with those relations that involve an agent. Here, philosophers (including the British Emergentists) focus on an epistemic question, namely the possibility of an explanation connecting the putatively emergent property with the properties of its physical constituents.

Consider a non-emergent property like mass: One can generally explain the mass of an object in terms of the sum of the masses of its parts. Given the existence of a successful explanation of this kind we would be inclined to regard mass as *not* being an emergent property. An explanation for why the object has its mass can be provided in terms of the sum of the mass of its parts. By contrast, there are properties for which no explanation is available. For example, at present we have no widely agreed upon explanation of the consciousness of a person in terms of the consciousness of its parts. The lack of such an explanation might lead some of us to consider the possibility that consciousness is emergent. However, the lack of an explanation of consciousness is not the same as the knowledge that there is no explanation. Unless the agent is God, the fact that an agent lacks an explanation does not entail that there is no explanation, simply that they have not yet found one or learned of one from someone else.

Knowing that there is no explanation is a special circumstance. There are some cases, for example, Bell's inequality, in which it is provable that some kinds of explanations are not possible. Bell showed that there are some phenomena predicted by quantum mechanics and observable experimentally which do not admit of an explanation in ways that we might intuitively expect. Specifically, Bell shows how the quantum mechanical phenomenon of entanglement must violate commonsense assumptions about locality. In this case, if we insist on local interactions alone, we will never account for the behavior of entangled particles.

Limitative theorems like Bell's are rare and precious things. They count as some of the greatest achievements in intellectual history. In general it is not the case that we will have such knockdown arguments against the possibility of explanation in the kinds of cases that traditionally interest emergentists: life, chemistry, psychology, etc. Limitative or no-go theorems are found in contexts where definitions are given in formal terms and with extreme precision. If there were an argument that showed some property simply cannot be given an explanation in terms of its basal properties, it would have a strong claim on being called emergent.

Mark Bedau's account of weakly emergent properties is built around the idea that some properties are in principle inexplicable given some set of initial constraints. The difference here is that weakly emergent properties are characterized in ways that make them independent of particular epistemic agents. His definition of weakly emergent macrostates of systems runs as follows:

> Macrostate P of S with microdynamic D is weakly emergent iff P can be derived from D and S's external conditions but only by simulation. (Bedau 1997: 378)

The kinds of macrostates that Bedau had in mind are exemplified by patterns that appear in cellular automata like The Game of Life.[7] Such computational systems can have some macrostate P that only appears once the system has run through n steps. The sequence of steps that constitutes the derivation of a weakly emergent property P is not compressible: In other words, there are no shortcuts to P. It might be tempting to dismiss the examples of weakly emergent properties that we find in cellular automata as mere artifacts of these systems; indeed it is possible to construct examples of weakly emergent patterns in a relatively straightforward manner. However, as Bedau noted,

[7] As Hu Richa and Xiaogang Ru note (2003) cellular automata (CA) can be characterized in terms of a quintuple set: {Cells, Cell Space, Cell State, Neighborhoods, Rules}, where cells are the basic objects or elements of the CA each having some individual state depending on the rules of the CA. Cell space is defined as the set of all cells and their values at some time. Neighbors are the set of cells surrounding any center cell and rules are the transition functions of cell states, mapping cell spaces to cell spaces (2003: 1047). The rules of the CA are defined as being maximally general with respect to the cells in the model and the application of rules updates each cell synchronically. See also Symons 2008: 487.

the concept of weak emergence has a potentially broader application than in toy cases like cellular automata.

Some phenomena in fluid mechanics are governed by partial differential equations with no analytical solutions. The Navier-Stokes equation is a famous example. Even though numerical solutions to Navier-Stokes are available and can serve as the basis for computational models of fluid dynamics, mathematicians have not been able to provide analytical solutions (solutions that, for example, provide functions relating, in this case, velocity, time, and position). Thus, a property of a real phenomenon (say the location of a particle in the fluid) that we might come to know (approximately) via a computational simulation can be called weakly emergent insofar as it is not immediately accessible to us even given knowledge of the software powering the simulation prior to running the simulation.

If we knew that the Navier-Stokes equation was the basis for the simulation that we relied upon, we would not be able to use that equation to find some relevant values of the system at some point in the future. It would not be possible given the current state of mathematical knowledge to predict where a particle carried along by the flow would be at some point given the equation alone. Instead, a computer model built around a numerical simulation of Navier-Stokes could give us an approximate location after running the appropriate number of steps.[8] Contrast this kind of derivability via simulation with the way one might determine the position of Jupiter at some date in the future using one's knowledge of its current position and the equations governing its motion. While a single computation would be sufficient to give the position of the planet at some future date, finding the disposition of the simulated fluid in our example would require an incompressible sequence of computations.

Weakly emergent properties are philosophically important insofar as they exemplify the thesis that there can be properties that are connected in a non-mysterious and non-enthymatic way to some set of initial conditions or base while not being explainable in terms of that base. The connection between the set of initial conditions and the emergent property in the case of weak emergence is simply the incompressible sequence of steps that must be run through in order for the property to appear. Notice, as Bedau (2008) points out, that this is not a feature of the subjective epistemic states of any particular audience. The incompressibility of the sequence is an objective fact about the emergent property. In this sense, there is no further explanation of the appearance of the property. The incompressible sequence of states that runs from the initial conditions to the macroproperty is our first example of a scientifically respectable brute fact that grounds the judgment that a property is emergent.

Another way into the notion of emergence involves the claim that there is a metaphysical difference between emergent properties and their basal properties. This difference requires more than having some distinctive relationship to the limits of

[8] See Jacques Dubucs 2006 for discussion of simulations of fluid dynamics and the relationship to the categories of weak and strong emergence.

explanation. For example, the properties of being an organism, or being conscious, can be regarded as metaphysically distinctive insofar as they are (if they are) ontologically novel relative to their so-called basal properties. These properties are not simply difficult (or impossible) to derive from the characteristics of the basal properties, as is the case for example in weakly emergent properties, but constitute a new and real kind of thing.

Accepting weak emergence does not commit us to any specific ontological claims with respect to weakly emergent properties. The distinction between weakly emergent properties and non-emergent properties is marked by factors extrinsic to those properties. So, for example, two patterns in a simulation might differ with respect to whether or not their derivations are compressible. The result of a simulation of a fluid might be the product of an incompressible sequence while the result of a simulation of a simple gravitational system might be amenable to a straightforward analytic solution that one could solve in a few steps with pen and paper. This difference is significant and theoretically interesting, but it is not enough to warrant treating them as ontologically different. The kinds of being the patterns on a computer screen have in both cases are more or less identical regardless of whether one pattern indicates (or manifests) a weakly emergent property.

To say that we are simply talking about patterns on a screen seems to beg the ontological question. Of course, if the two patterns are both of this type, there can be no interesting ontological difference. As we have seen, what makes the patterns emergent or not is extrinsic to them. The patterns are related to the algorithms or functions that generate them in ways that are philosophically interesting. Thus, one might opt to focus on the objective mathematical or logical features of weak emergence rather than simply identifying weak emergence with patterns on a screen. From this perspective, one regards weak emergence as a property of some abstract mathematical objects. Putting weakly emergent properties in the ontological category of mathematical objects would not make weakly emergent properties distinctive, insofar as they would then simply be one among many kinds of abstract mathematical object.

4. Brute Facts about Strong Emergence

Unlike weakly emergent properties, strongly emergent properties are characterized as being emergent relative to the ontologically fundamental features of the world. If there are any, strongly emergent properties are marked by intrinsic features that make them distinctive additions to the world's ontological inventory. To put it another way, if consciousness were a strongly emergent property then pace the author of Ecclesiastes, the emergence of consciousness at some point in the past marks the appearance of a genuinely new thing under the sun (Ecclesiastes 1.9–1.14).

Entities that are strongly emergent must be understood as distinct from the properties of the prior stuff of the universe in a way that is metaphysically as well as logically significant. From a physicalist perspective, ontological emergence can seem like the product of confusion. After all, if our theory locates all causal powers at the level of the ontologically basic units of our metaphysics, the claim that there will be new causal powers which are not had by those units will be ruled out a priori. In the late 1990s Jaegwon Kim provided a set of arguments designed to block ontological emergence. He focused on what he sees as the distinctive feature of so-called strongly emergent properties: reflexive downward causal power. He assumes a mereological characterization of emergent properties, where the whole is somehow acting on its parts. He argues that this is an impossibly circular phenomenon since, if causation is transitive, it would entail self-causation. Causation takes place over time and involves property changes that make "self-causing" unacceptably paradoxical. Kim concludes that the kind of self-causation or self-determination that is required for emergence is "an apparent absurdity" (1999: 28). The contradiction that seems implicit in such cases implies that the putative causal powers of higher-level properties are always excluded by the causal properties of their underlying physical components. So, while we can certainly identify new patterns and phenomena for instrumental or other reasons, these can only be shown to be real given the identification of a unique set of causal powers (Kim 1999: 33).

Given these arguments, advocates of strong emergence could disagree with Kim's view of individuation or that physicalism is complete. At the very least, if one claims that non-fundamental properties are real or that they possess causal powers that are not possessed by units at the fundamental level, one is claiming that something more than the physicalist's proposed list of fundamentals is needed for a complete account of reality. Physicalists have consistently found completeness, in the form of the causal closure of the physical world, to be the most important feature of the view.

Familiar anti-physicalist arguments have focused on cases, like the case of phenomenal experience, which cannot be successfully accounted for by physicalism. At this point, some physicalists have opted for an a posteriori view of fundamentality such that whatever this additional extra emergent something is, it can simply be added to the proposed list of fundamentals. This approach to ensuring completeness has been taken by David Chalmers and, to some extent, more recently by Kim himself.

If physics delimits our fundamental ontology then strongly emergent properties would fall outside of the natural world. As David Chalmers writes: "Strong emergence has much more radical consequences than weak emergence. If there are phenomena that are strongly emergent with respect to the domain of physics, then our conception of nature needs to be expanded to accommodate them" (2006: 246). Notice that the ontological inventory of nature only needs to expand if one believes that physics (presumably some as yet unrealized physics) is ontologically complete. By ontological completeness here we mean that there is no truth about the kinds of things that exist that is not derivable from the truths of (the finished) physics.

Terrence Horgan presents the difference between physicalists and emergentists as follows: "A physicalist position should surely assert, contrary to emergentism . . . that any metaphysically basic facts or laws—any unexplained explainers, so to speak—are facts or laws within physics itself."[9] Thus the plausibility of strong emergence depends, at least in part, on our understanding of the completeness of physicalism: Can the physicalist assume some version of physics that contains a complete set of *unexplained explainers*? For the British Emergentists, as we saw above, it was simply a matter of empirical fact that physics could not explain brute facts about chemistry. Thus, from the emergentist perspective there are unexplained explainers that fall outside of physics.

How can we make progress in this kind of dispute? Emergentists and physicalists share some common methodological ground that can serve as a starting point. As we saw in section 2, while emergentists and physicalists hold opposite positions with respect to unexplained explainers, they both do so on the basis of empirical considerations.[10] So, for example, Andrew Melnyk (2003), in *A Physicalist Manifesto*, spends much of the latter half of the book arguing for physicalism on the basis of scientific evidence. David Papineau argues that the principal motivation for accepting physicalism is reflection on the history of science.[11] Daniel Stoljar (2010) agrees with Papineau on the empirical origins of physicalism, pointing out that few of us are brought to physicalism by a priori reasoning and that the denial of physicalism does not involve any obvious logical contradiction or conceptual error. He compares its status to that of the theory of evolution or of continental drift. Denying physicalism, he argues, is not philosophically absurd, but it does put one in conflict with science and scientifically informed common sense (Stoljar 2010: 13).[12] Melnyk, Papineau, and Stoljar offer reasons in support of physicalism motivated by "scientifically informed common sense" rather than from a priori considerations. The implication here is that support for physicalism should be withdrawn if there is sufficient commonsense or scientific justification for doing so. Furthermore, if physicalism were found to have consequences that are contrary to scientifically informed common sense, then support for it would be weakened accordingly.[13]

It is difficult to identify a set of principles concerning metaphysical fundamentality that most physicalists would endorse (Dowell 2006). One relatively uncontroversial point is the shared assumption that *the physical world is causally closed*. The second is the assumption that *individuation involves unique causal powers*.[14] The third is a commitment to *Hume's dictum*. Jessica Wilson explains Hume's dictum as the view that "there are no metaphysically necessary connections between distinct, intrinsically

[9] Horgan 1993: 560 (quoted in Tim Crane 2010).

[10] For further elaboration see Symons 2015. [11] Papineau 2001: 7.

[12] Given that Stoljar goes on to argue that there is no version of physicalism that is both defensible and non-trivial, readers are likely to conclude that conflict with scientifically informed common sense is unavoidable.

[13] Physicalism and the ontology of physics are not the same thing. As Hempel noted, physics may progress in ways that are not aligned with the assumptions that motivate physicalism (Hempel 1969). Prominent among these assumptions are, for example, locality.

[14] Kim 1999.

typed, entities."[15] The converse of Hume's dictum is the claim that if there *are* metaphysically necessary connections between entities or/properties then they *are not* distinct. In order for the physicalist to preclude brute strong emergence, they must be in a position to guarantee that there are no properties or entities that are metaphysically distinct of the physical. There are few explicit arguments for physicalist completeness claims in the philosophical literature. This is significant in this context insofar as completeness is essential to arguments against the possibility of strongly emergent properties. The view that physicalism can, in some sense, provide a complete inventory of all the facts is often associated with David Lewis' Humean supervenience. He famously argues that:

> Humean supervenience is named in honor of the great denier of necessary connections. It is the doctrine that all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another. (But it is no part of the thesis that the local matters are mental.) We have geometry: a system of external relations of spatiotemporal distances between points. Maybe points of space-time itself, maybe point-sized bits of matter or aether or fields, maybe both. And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated. For short: we have an arrangement of qualities. And that is all. There is no difference without difference in the arrangement of qualities. All else supervenes on that. (Lewis 1986: ix)

Lewis' view was that all facts ultimately supervene on the fundamental *physical* facts, so the way to interpret his talk of qualities in the account of Humean supervenience is, presumably, in terms of physical properties. So, for example, elsewhere he writes: "The world is as physics says it is, and there's no more to say" (Lewis 1999: 34). If correct, this view rules out the possibility of strong emergence absolutely. There can be nothing that wasn't already somehow included in the great mosaic of basic Lewisian facts. As Mark Bickhard (2011) and others have noted, it is very difficult to make sense of the claim that the relations involved in quantum entanglement supervene on particular points and their individuated values (see also Butterfield 2006).[16]

Others might regard completeness as equivalent to capturing all true causal judgments. There are a variety of other ways one could imagine carving up the question of completeness for a metaphysical system. At the very least, to determine completeness we need to decide on the relevant set of truths that we hope to capture and we need to specify as precisely as possible the ontology of objects and the laws that the metaphysical position proposes. This is, of course, a pretty unwieldy task for most non-trivial

[15] Wilson 2010.

[16] Lewis also faces the challenge of reconciling vector fields like electromagnetism with the idea that there is a fundamental level of points with single values. Since vectors seem intrinsically relational it has struck critics like Bickhard (2011), Karakostas (2009), and Butterfield (2006) as a significant obstacle. See Busse (2009) for an attempt to reconcile Humean supervenience with vector fields. At the very least, this problem points to the absence of an easy fit between Lewisian metaphysics and modern science. It also suggests that an ontology inspired by contemporary physics would not necessarily look like the foundationalism envisioned by Lewis.

systems. However, for the purposes of understanding completeness we can treat metaphysical frameworks abstractly by recasting them as *generative fundamentals*. Generative fundamentals are the set of total states of a world and the possible transformations on that set. They would be equivalent to the set of unexplained explainers mentioned by Terrence Horgan (1993).

Elsewhere, I explain in detail how to think of a metaphysical framework in terms of generative fundamentals for the purpose of determining whether it is complete (Symons 2015). When it comes to the problem of determining completeness, there are two significant challenges. First, there is the challenge of excluding the kinds of interactions between states and transformations that lead to truths about the system that are not derivable from the generative fundamentals. This challenge can be overcome by anticipating all possible interactions (the Leibnizian way) or by denying potentially problematic interactions between states of the system (the Humean way).[17] In addition to preventing or anticipating interaction, the proponent of metaphysical completeness faces a stranger problem, namely the problem of transients.

A transient is defined as a state or sequence of states or a subset of that sequence of states that has a first member.[18] This way of understanding transients is similar to the concept of transients as they appear in a Markov chain analysis. However, for simplicity's sake, we need not assume anything about probability or randomness here. In a Markov chain if there is some non-zero probability that the system will never return to a state, we say that this state is transient. If a state is not transient, it is recurrent.[19] For any generative fundamentals, F, the possibility of transients entails that F might have resulted from some other generative fundamentals F^*.

There will be some cases where F^* is epistemically inaccessible from the perspective of agents in some system governed by F. More intuitively, for any system or universe that we imagine completely captured by some generative fundamentals, we cannot exclude the possibility that the set of fundamentals themselves are the result of some non-repeating process—a transient—that is not part of that set. One could imagine a simple series of states in some oscillating universe, for example, where the denizens live between a Big Bang and a Big Crunch. They might have developed a cosmological theory that correctly predicts all the truths of the future of their universe and perhaps does a good job retrodicting the past states of the universe as well. However, the apparent completeness of this account is threatened by the possibility of a transient that was part of the history of the universe, but not part of the cycle of bang and crunch into which their universe has settled.

Properties in some system governed by F can be such that, relative to the successor or predecessor system, they can be called emergent. The kind of emergence exhibited

[17] I discuss these alternatives in detail in my 2015. For a response to Kim-style exclusion arguments see my 2002.

[18] Booth 1967.

[19] For an overview of Markov chains see Booth 1967.

by these systems can be called strongly emergent insofar as the novel system's generative fundamentals differ from the system that preceded it. In this sense, apparent completeness at the level of generative fundamentals governing the later system would not be sufficient to account for all the metaphysically basic features of reality. The purpose of the argument from transients is simply to note a limitation on attempts to use the completeness of some set of generative fundamentals as the basis for an argument against emergence.

At this point, the advocate of fundamentalist metaphysics might respond that one can opt for an a posteriori view of the fundamentals such that whatever this additional extra emergent something is, it can simply be added to the proposed list of fundamentals in order to ensure completeness.[20] As argued in Symons (2015) and by Hempel (1969), an ad hoc strategy of adding to the list of fundamentals as required by new evidence is insufficient if one's goal is to defend something like physicalism against the possibility of emergence. In any event, given the possibility of transients, one's metaphysics can fail with respect to the project of generating a complete list of fundamentals even when we allow our account of the fundamentals to be modified a posteriori. The possibility of an incomplete fundamental metaphysics turns out to be unavoidable and cannot be remedied by the addition of extra principles or categories. This is because, as we have seen even in cases where the present and future states of the natural world appear to have been completely captured by some set of fundamental principles, the possibility that these principles themselves are the result of the process of emergence cannot be excluded.

Emergent properties are not necessarily indicators of trouble with respect to scientific explanation as we will see in the final section. However, they run counter to the ambition of metaphysical fundamentalism and particularly to a naïve physicalist version of the PSR.

5. Scientific Rationality, Bruteness, and the PSR

Section 4 sketched some reasons for doubting the kinds of completeness claims that are central to anti-emergentist metaphysical positions like physicalism. I have not made a positive case for emergentism, but have focused instead on a defining characteristic of emergentism, namely the central role of brute facts.

The bruteness of strong emergence provokes a basic question about the intelligibility of the world: Does belief in genuinely emergent properties involve a commitment to the view that some basic features of the natural world are unintelligible? If so, such a commitment seems damning to those committed to the PSR. As we have seen, a virtue of physicalism is its optimistic commitment to the possibility of complete explanations. Physicalism, in this sense, satisfies the PSR since according to physicalism all facts are

[20] Or the fundamentals can be modified in some other way in order to ensure completeness.

explained by their relation to the physical facts. It is notable that early rejections of strongly emergent properties are motivated by precisely this kind of concern. Arthur Pap writes, for instance:

> To speak of absolute unpredictability, unpredictability once and for all, convicts one, in fact, of metaphysical obscurantism, motivated perhaps by a subconscious hostility against the faith in the omnipotence of science. Indeed, I would not wish to deny that those who, following Alexander, recommend 'natural piety' in the face of 'absolute novelty', most likely have no clear idea as to what they mean by such 'absolute novelty'. (1952: 303–4)

What Pap means by 'faith in the omnipotence of science' is equivalent to a commitment to a scientific version of the PSR, and he regards its opponents, those who entertain the possibility of absolute novelty, as obscurantists. At first glance, many of us find the idea of brute facts intellectually repulsive. Is this reaction warranted? Alexander Pruss notes that the claim that some event or state of affairs is uncaused or unexplainable is difficult to accept (2006: 3).

Usually our skeptical reaction to brute facts is appropriate. To take Pruss' example, if we hear that the disappearance of an airplane is unexplained we naturally assume that what is meant is simply that it has not yet been explained, certainly not that it is unexplainable. To claim that the disappearance is unexplainable would be to say something quite extraordinary.

Our intuitive reaction is motivated to a certain extent by faith in the project of scientific explanation and perhaps more deeply it is a product of a more basic commitment to the intelligibility of the natural world. However, it is more likely that our initial skepticism is primarily fueled by the extraordinary nature of the claim that some specific state of affairs is a brute fact. The claim that the airplane's disappearance is unexplainable, for example, is simply an unacceptably exotic state of affairs. Our reaction can be understood to be equivalent to the denial of the positive statement of the brute fact: "Planes don't disappear for no reason." Giving or withholding credence with respect to an exotic state of affairs is fully compatible with skepticism about other things. In ordinary life one can be skeptical with respect to my neighbor's claims that he was miraculously healed while simultaneously doubting the expertise of one's local medical professionals or perhaps even of the foundations of modern biology. Similarly one might have good reasons for being skeptical of say the central dogma of modern biology, while trusting most of what we learn from biological science. Thus, one could be skeptical concerning some candidate brute fact while simultaneously being skeptical concerning more general versions of PSR, for example, the claim that God has a plan for all things.

To accept the PSR as a methodological heuristic rather than as a metaphysical principle is simply to adopt a skeptical attitude when someone suggests that there is no explanation of some event or phenomenon. This skepticism is justified by induction from our shared history of inquiry and from our own experience. We learn from experience that, with some prominent and important exceptions, being optimistic about the possibility of inquiry is a good policy.

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