nate because Kitcher has long recognised that the presumption that the world must be ontologically unified is a weakness of his unificationist approach to explanation. In his words: "it looks as though the approach must defend the *prima facie* implausible thesis that the world is necessarily unified" (Kitcher 1989, p. 496). Kitcher's initial response to this problem was to "recommend rejecting the idea that there are causal truths that are independent of our search for order in the phenomena. Taking a cue from Kant and Peirce, we adopt a different view of truth and correctness" (1989, p. 487). This is *a* solution to the problem created by the possibility of ontological disunity, but it is not a solution that genuine realists, which R&S purport to be, should be happy to endorse. In effect Kitcher is proposing that we compromise realist ambitions by adopting a Kantian position in which order is, at least in part, projected onto the world. Kitcher (1989, 1994) is quite explicit about the Kantian flavor of his views.

Kitcher has recently undergone a change of heart. He now tells us that his "grand project of articulating the most unified vision of nature that we could achieve . . . is mistaken" (Kitcher 1999, p. 347). In 1989 Kitcher was a grand unifier, but the 1999 Kitcher is an advocate of "Modest unificationism." Modest unificationism involves accepting that "the world may be a disorderly place, that the understanding of its diverse phenomena may require us to employ concepts that cannot be neatly integrated" (1999, p. 339). Modest unificationism involves looking for unity where we can find it, while accepting that there may be limits to the amount of unity that is there to be found. It is a position that should be congenial to genuine realists because it does not involve presuppositions about the ontological structure of the world.

R&S begin by observing that "Philosophy progresses with a tide-like dynamic." The low tide of logical positivism was more than half a century ago, but it seems that the high watermark of realism has not been reached, if their article is any guide. Their conviction that science should aim to describe the world as a single working machine appears to be an unwarranted remnant of the strong unificationism characteristic of the heyday of logical positivism. Kitcher has abandoned a similar conviction, and I can only urge R&S to follow his lead. Mainstream realism is compatible with the weak unificationism that Kitcher (1999) now advocates but not with the form of unificationism that R&S currently favor.

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Reduction, supervenience, and physical emergence

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Abstract: After distinguishing reductive explanability in principle from ontological deflation, I give a case of an obviously physical property that is reductively inexplicable in principle. I argue that biological systems often have this character, and that, if we make certain assumptions about the cohesion and dynamics of the mind and its physical substrate, then it is emergent according to Broad's criteria.

Reduction is ambiguous in three ways. It may mean inter-theoretic reduction, the reduction of fundamental kinds of things (substance, traditionally), or that certain particular entities (objects, processes, or properties) can be eliminated without any loss of explanatory power in principle. I will ignore inter-theoretic reduction. The reduction of the number of fundamental kinds of things is best called *ontological deflation.* I will assume the closure of the physical (physicalism), and I will assume that all scientific explanation is in some sense causal and that explanatory power is lost only if the causal nature of a higher level entity is not in principle completely reductively explicable.

Despite supervenience, if explanatory reducibility fails in principle for some entity, then it is emergent. If there is no possible argument (deductive or inductive) from the parts, their intrinsic properties, and their relations to the full causal powers of the entity itself, then reductive explanation fails in principle. I will show that this holds for certain obviously physical properties of some systems under certain specific conditions. I will further argue that this helps to identify a class of systems for which reductive explanability fails. In these cases, even if physicalism is true, they are emergent. This idea of emergence fits C. D. Broad's criteria (Collier & Muller 1998).

The planet Mercury was found in the 1960s to rotate on its axis three times for each two times it revolves around the sun. This was extremely surprising because it had been thought that it would be in the same 1:1 harmonic as our moon-earth system. There are several more complex harmonic relations in the solar system. It is well known that the three-body gravitational problem is not solvable analytically, but it can be solved numerically, in principle, to any degree of accuracy we may require for any finite time (this is true for any Hamiltonian system). However, these cases involve the dissipation of energy through tidal torques unless the system is in some harmonic ratio. We would like, ideally, a complete explanation (possibly probabilistic) of why Mercury is in a 3:2 harmonic. Because of the high mass of the sun and the proximity of Mercury to the sun, the high tidal torque dissipates energy reasonably quickly in astronomical time; therefore, Mercury is likely to end up in some harmonic ratio in a finite amount of time. The central explanatory problem then becomes: why a 3:2 ratio rather than a 1:1 ratio, like our moon, or some other harmonic ratio?

We cannot apply Hamiltonian methods, because the rate of dissipation is roughly the same as the characteristic rate of the phenomenon to be explained. If the dissipation rate were small, then we could use an approximate Hamiltonian system; if it were large, we could use a step function. We are left with the Lagrangian. It is well known that these are not always solvable even by numerical approximation. I will give an intuitive argument that the Mercury's harmonic is such a case. Each of the possible harmonics is an *attractor.* Why one attractor rather than another? If the system were Hamiltonian, then the system would be in one attractor or another. In principle we could take into account the effects of all other bodies on Mercury and the sun (assuming the universe is finite, or at least that the effects are finite) and decide with an arbitrarily high degree of accuracy which attractor the system is in. However, given the dissipative nature of the system, it ends up in one attractor or another in finite time. If we examine the boundaries between the attractors, they are fractal, meaning that every two points in one attractor have a point between them in another attractor, at least in the boundary region. This is as if the three-body gravitational problem had to be decided in finite time, which is impossible by numerical approximation (the problem is noncomputable, even by convergent approximation). Therefore, there can in principle be no complete explanation of why the Mercury-sun system is in a 3:2 harmonic. There is approximately a one-third chance of 3:2 capture, one-half chance of a 1:1 capture, and the rest of the harmonics take up the rest of the chances. The chances of a 3:2 capture are good but not that good. The system is obviously physical, but it has a nonreducible property. This property fits Broad's notion of emergence.

How does this apply to the mind? It is highly likely that there are nonlinear dissipative processes in the brain in which the rates of the processes are of the same order as the rate of dissipation. There are also likely to be huge numbers of attractors. The larger the number of attractors, the lower the probabilities of capture in any particular one generally; therefore, a complete reductive explanation seems highly unlikely. This case is certainly true for many biological processes (as in development and in evolution; see Brooks & Wiley 1988; Kauffman 1990). The brain is, after all, biological. We must explain backwards from the attractors that are formed, that is, downwards from constraints on the constituent physical processes of the order found in the attractors that "win" (Campbell 1974).

But the situation is worse. Certain properties hold a system together (called *cohesion* in Collier 1986; 1988; Collier & Hooker 1999; Collier & Muller 1998). Cohesion is the unity relation for a dynamical system (previous references; Collier 2002). The unity relation is the basis of the identity of an entity. If the property of cohesion is nonreducible, then the object is nonreducible (not the *kind* of object; that can vary). It is certainly possible that the cohesion of the mind, if there is such a cohesive thing, is of this sort. Kim's arguments address ontological deflation (and kinds of objects), not emergence in particular dynamical systems. It is quite possible for an entity to be physical in every respect but not to be reducible in any way that is relevant to complete scientific explanation, even in principle.

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Supervenience: Not local and not two-way

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Abstract: This commentary argues that Ross & Spurrett (R&S) have not shown that supervenience is two-way, but they have shown that all the sciences, including physics, make use of functional and supervenient properties. The entrenched defender of Kim's position could insist that only fundamental physics describes causal relations directly, but Kim's microphysical reductionism becomes completely implausible when we consider contemporary physics.

Ross & Spurrett (R&S) point out that the definition of supervenience as (roughly) no change in the supervening properties without a change in the subvening properties, does not imply realizer functionalism (or internalism) unless the relevant subvening change has to occur in the realizer (target article, sect. 2.2). However, they go on to cite Kim (1998), defining supervenience such that if the mental properties of something are to be different, there must be a difference in the physical properties *of that thing.* This appears to rule out externalism, according to which mental properties depend on relations to the environment. If a change in relations does count as a change in the realizer, because relational properties are included in the subvenient base, that reconciles this definition of supervenience with externalism and allows the causal exclusion argument to proceed but with realizer functionalism, not role functionalism, as its target. It seems that Kim's causal exclusion argument relies on local rather than merely global supervenience, but it also seems that local supervenience is less plausible, and certainly the completeness of physics does not entail local supervenience.

A confusing thing about this article is the notion of multiple supervenience and the role it plays in R&S's attempt to reconcile the causal closure of physics with the causal efficacy of supervenient and functional properties. R&S argue that there is two-way supervenience, but they do not show that there is a modal rather than merely an epistemic dependence of, say, physical properties on functional ones. Nothing they say defends the implausible claim that there can be no change in physical properties without a change in mental properties. Rather, they argue persuasively for multiple realizability and the indispensability of functional properties in science.

As R&S diagnose it, Kim's causal exclusion argument threatens to reduce the special sciences other than physics to stamp collecting. To this diagnosis it may be objected that nothing is being taken away from the special sciences by denying that the properties to which they refer in their theories are causally efficacious. After all, the supervenient properties are realized, and the realizers are causally efficacious. Hence, in any concrete case, someone who uses, say, the language of mental states to talk about behaviour and its causes could be regarded as *referring* to physical tokens of the supervenient types, and there are causal connections between those physical states, albeit ones that are of no salience to us. Therefore, according to this response, in "S's belief that *p* caused them to do X," the referent of "S's belief" is a physical state that really does cause the physical state that tokens S's doing X. Saying that beliefs cause actions is elliptical for saying that beliefs are tokened by physical states that cause physical states that token actions. Therefore, it may be argued that the special sciences are tracking a rich causal structure, and therefore doing real science and not mere stamp collecting, but that structure is being described indirectly by means of supervenient properties. Psychology, say, may issue predictions and systematise data in a way that would be epistemically inaccessible to physics, but mental causation is really between physical realizers of mental states. However, this need not be instrumentalism because it may be conceded that supervenient properties are real features of the world and not mere constructs, while maintaining that they only have causal power vicariously.

R&S point out that much of physics is not fundamental and describe properties that are supervenient on atomic and subatomic realizers. Suppose that physics does describe the world by means of supervenient functional properties and that temperature and pressure are examples. There is no doubt that describing the macroscopic properties of a gas in these terms allows for reliable predictions in terms of laws. However, someone of Kim's persuasion could argue that an increase in the pressure of a gas at constant volume does not cause anything; rather, the increase in temperature is a consequence of many microevents that happen to be amenable to a more convenient description than listing them all (and note that there is a physical story to be told about how the universal properties of differently realized macrostates arise). Temperature is a coarse-grained functional property and summarises the statistics of a multitude of microevents. It is a real property but not a causal one. On this view, there is physics, there is stamp collecting, and there is some physics that is stamp collecting.

Which brings us to fundamental physics, which presumably describes the domain where the real causal action is happening in the movements and interactions of microbodies. That quantum phenomena have led to the return of the spectre of action at a distance to physics is well known. This is particularly apposite to metaphysics when local supervenience claims are at issue because arguably what quantum nonlocality requires is not action at a distance *per se,* but the denial of local supervenience. Entangled states of joint systems are just those that violate the principle that the joint state of the whole should supervene on the states of the parts, and, as is well known, Bell's theorem tells us there is no consistent way of attributing states to the parts from which the properties of the joint system can be recovered (without action at a distance). Furthermore, things only get worse for the advocate of microcausation as the only real causation. Quantum field theory does not apply at arbitrarily short-length scales, and researchers in quantum gravity are exploring theories that dispense with spacetime altogether and then try and recover it as an emergent feature of something else. Kim, or anyone who similarly thinks that the real causal processes are only at the fundamental physical level, would then be faced with claiming that there are no true causes in space and time. At that point, if not before, it is surely right to conclude with R&S that the causal explanations of the special sciences are as genuine as those of even fundamental physics.

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