Non-reductive Physicalism and Degrees of Freedom*

Jessica Wilson†

Draft: November 20, 2008

Some claim that Non-reductive Physicalism (NRP) is an unstable position, on grounds that NRP either collapses into reductive physicalism (contra *Non-reduction*), or expands into emergentism of a robust or “strong” variety (contra *Physicalism*). I argue that this claim is unfounded, by attention to the notion of a degree of freedom—roughly, an independent parameter needed to specify states upon which the law-governed properties and behavior of a given (type of) entity functionally depend. In particular, I argue that what I call “eliminations in DOF”—when strictly fewer degrees of freedom are required to characterize certain special science entities than are required to characterize (systems consisting of) their composing physical (or physically acceptable) entities—provide a basis for making sense of how certain special science entities can be both physically acceptable and ontologically irreducible to physical entities.

1 Introduction

Non-reductive physicalism (NRP) consists of the following two theses:

1. All broadly scientific entities are nothing over and above physical entities¹ (*Physicalism*)

*Please note that this is a work in progress. Thanks to audiences at Tufts University, the University of Kentucky, the University of Toronto, the 2005 Southern Society for Philosophy and Psychology panel on realization and emergence, the 2005 Midwest APA symposium on physically acceptable emergence, the 2005 ‘Descrying the World in Physics’ conference at Rutgers, and the 2006 On-line Philosophy Conference for helpful comments and questions. Special thanks to Benj Hellie, Jonathan McCoy, Noa Latham, Jeffrey Yoshimi, and two anonymous referees, for detailed feedback on previous versions, and to Michael Strevens for his OPC comments.

†Department of Philosophy, University of Toronto; jessica.m.wilson@utoronto.edu

¹The entities in question may be of any relevant ontological category (property, event, substantial particular, etc.); broadly scientific entities are entities that are among the subject matters of any of the sciences, from fundamental physics up through linguistics, psychology, and beyond. Note that structured or unstructured collections or systems of entities are also entities in this broad sense. *Physicalism* is neutral, I will assume, on whether entities that are not broadly scientific—perhaps
2. Some broadly scientific entities are ontologically irreducible to physical entities—i.e., are not identical to any physical entities or systems consisting of physical entities in physical relation, nor to any boolean or mereological combinations of such entities or systems (Non-reduction).

Some claim that NRP is an unstable position, either collapsing into reductive physicalism (so denying Non-reduction) or expanding into emergentism of a robust or “strong” variety (so denying Physicalism). I argue here that this claim is unfounded. NRP occupies a viable middle ground between reductive physicalism and robust emergentism, according to which some phenomena are (as I will sometimes put it) ‘weakly ontologically emergent’ from physical phenomena.

My strategy is as follows. Standardly, the physical entities are the relatively fundamental entities treated by current or future (in the limit of inquiry, ideal) physics. By these lights, entities treated by the special sciences are generally not physical, though many are uncontroversially intuitively physically acceptable, in being ontologically nothing over and above physical entities. A good way to establish the viability of NRP, then, would be to provide an account of the relation between physical entities and certain uncontroversially physically acceptable special science entities, which shows that and how the latter conform to both Physicalism and Non-reduction. Here I provide such an account, based in the notion of a degree of freedom (DOF)—roughly, an independent parameter needed to specify states upon which the law-governed properties and behavior of a given (type of) entity functionally depend.

---

2. Most notably, Kim claims this, as in his 1989 and 1993a.
3. The qualifier 'ontologically' tracks a relevant point of departure from Bedau's (1997) account of weak emergence. Bedau’s account also aims to characterize emergence as compatible with physicalism, but does so in epistemological terms (whereby ‘weakly emergent’ phenomena are derivable, but only by simulation, from physical phenomena).
4. It is also required, in order to guarantee physicalism’s incompatibility with panpsychism, that the physical entities not be fundamentally mental (that is, individually neither have nor bestow mentality). On my preferred formulation (see Wilson 2006) an entity in world w is physical just in case it is (approximately accurately) treated by current or future (in the limit of inquiry, ideal) physics at w, and is not fundamentally mental. See Hellman and Thompson 1975, Papineau 1993, Ravenscroft 1997, Papineau 2001, and Loewer 2001 for variations on this theme.
5. Surprisingly little attention has been to the role degrees of freedom might play in illuminating issues in the metaphysics of science. Thalos 1999a and 1999b are notable exceptions. The notion of degree of freedom at issue here will draw upon Thalos 1999a for confirmation; in general, however,
relations that may hold between the DOF needed to characterize certain special science entities, and those needed to characterize (systems consisting of) their composing physical (or physically acceptable) entities; these correspond to what I call reductions, restrictions, and eliminations in DOF. I then argue that eliminations in DOF—when strictly fewer degrees of freedom are required to characterize certain special science entities, relative to those needed to characterize (systems consisting of) their composing entities—provide a basis for making sense of how special science entities can be both physically acceptable and irreducible to physical entities (that is, weakly emergent).

2 Degrees of freedom and special science entities

2.1 Degrees of freedom

The expression ‘degree of freedom’ (DOF) has several uses in scientific contexts. On the use at issue here, a DOF is, again roughly, one of a minimal set of independent parameters upon which the law-governed properties and behavior of a (token of a given type of) entity (again, including systems) functionally depend.\(^6\) Two immediate refinements are needed.

First, the parameters are those required to specify a (token of a given type of) state of the entity upon which its governing laws more explicitly depend, which may be either a partial state (as, e.g., the configuration state of an atom) or a complete state (as, e.g., the micro-state of a statistical mechanical ensemble) of the entity at issue. (For simplicity, henceforth I won’t explicitly distinguish between tokens and types of entities and states.) Call states upon which the law-governed properties and behavior of an entity \(E\) functionally depend the ‘characteristic states’ of the entity. DOF in the relevant sense are then parameters that are part of a minimal set needed to describe an entity as being in a characteristic state.\(^7\)

---

\(^6\)This is a generalization of the definition of ‘degree of freedom’ in the *Encyclopaedic Dictionary of Physics* (1961, p. 274): “The number of degrees of freedom of any mechanical system is the minimum number of coordinates required to specify the motion of that system.”

\(^7\)As Thalos (1999a, p. 9) puts it: “(Def.) \(X\) is a physically independent quantity or a degree of
Second, given an entity and characteristic state, the associated DOF are relativized to choice of coordinates, reflecting that different sets of parameters may be used to describe an entity as being in the state.\footnote{As Thalos (1999a, p. 9) puts it: “Different mechanical theories may assign the roles of degrees of freedom to different physical quantities. So I shall say that (Def:) $X$ is a physically independent quantity or degree of freedom of a system $a$ according to a theory or scheme of representation $T =_{df} X$ is designated by $T$ to be among those quantities whose magnitudes shape the state of $a$.\textquotedblright\n
}{8}

More precisely, then, the operative notion of DOF is as follows:

\textit{Degrees of Freedom (DOF)}: For an entity $E$, characteristic state $S$, and set of coordinates $C$, the associated degrees of freedom (DOF) are parameters in a minimal set, expressed in coordinates $C$, needed to characterize $E$ as being in $S$.

For short, one could write $DOF(E, S, C) = \{p_i\}$.\footnote{As we’ll see in §2.2, the notion of DOF could be further refined to incorporate the allowable range of values associated with each of the parameters. The simpler version is suited, however, for tracking the eliminations in DOF that, I will suggest, are at issue in weak ontological emergence.}{9} In what follows I will often speak in abbreviated terms of DOF needed to “characterize” $E$, with the coordinates and characteristic state at issue assumed.

Some further clarifications are in order: \footnote{Thanks to a referee for pointing out the need for several of these.}{10}

- As per the background appeal to states relevant to an entity’s law-governed properties and behavior, the characteristic states tracked by DOF are nomologically possible states (as opposed to metaphysically possible states, supposing these differ) for the entities at issue. For simplicity, I’ll usually drop the qualifier ‘law-governed’ when speaking about an entity’s properties and behavior.

- The properties and behavior of different entities (entering, perhaps, into different laws or treated, perhaps, by different sciences) may be functionally dependent on the same characteristic state (as with, e.g., the configuration state).

- Relatedly, for present purposes the main cash value of attention to DOF lies in the fact that DOF track the \textit{details} of an entity’s functional dependence on its characteristic states, in a more fine-grained way than states themselves do. To prefigure

\begin{center}
\textit{freedom (or, alternatively, one of the freedoms) of a system $a =_{df} X$ is among those quantities whose magnitudes shape the state of $a$.\textquotedblright}\n\end{center}

\textit{What it is for a quantity to “shape” a state, in Thalos’ terms, corresponds to what it is for a parameter to be part of a minimal set needed to specify the state (as relevant to the entity or system’s law-governed properties or behaviors), in my terms.}
a bit: what I will be exploring here is the idea that the fine-grained details concerning functional dependence encoded in the DOF needed to characterize a given broadly scientific entity serve as a plausible basis for the ontological individuation of the entity, as distinct (or not) from other broadly scientific entities.

- Given how DOF are defined (as being parameters that are one of a minimal set required to specify the state, the number of DOF needed to characterize the entity as being in a characteristic state will be the same, whatever coordinates are at issue. Again, to prefigure: this relativization won’t play a role in what follows, since the relation between (sets of) DOF that will be at issue will be in place whatever the (fixed) choice of coordinates.

- I assume that scientists have principled (presumably theoretical/ metaphysical) reasons for associating particular DOF with a given state.11 My concern is not with how scientists arrive at appropriate sets of DOF, but rather with how the DOF they deem appropriate in theorizing about a given special science entity are related to the DOF they deem appropriate in theorizing about lower-level entities (including and especially those composing the special science entities).

- Relatedly, I assume that we can, however fallibly, give a broadly realist interpretation to various aspects of scientific theories, including DOF (and associated entities and states)—an assumption that should be acceptable to the parties to the physicalism debates that are my concern, who uniformly look to the sciences for (at least some) ontological insight. From a scientific point of view, DOF provide a basis for specifying the states relevant to the laws governing an entity;12 from a metaphysical point of view, DOF represent (via the associated states) what is relevant to ontologically characterizing an entity’s law-governed properties and/or behavior.

Some paradigmatic characteristic states, and associated DOF, are:

11 As Brad Monton points out, as a technical manoeuvre any $N$ DOF each taking real values may be mapped 1-1 onto the reals: since there are only continuum many ordered $N$-tuples, every distinct assignment of values can be mapped onto a distinct real number, thereby “coding” the state description with only a single parameter.

12 Such functional dependence may be described in various ways; hence the relativization to coordinates.
1. The *configuration state*: tracks position. Specifying the configuration state for a free point particle requires 3 independent parameters (e.g., \( x, y, \) and \( z \); or \( r, \rho, \) and \( \theta \)); hence a free point particle has 3 configuration DOF, and a system of \( N \) free point particles has \( 3N \) configuration DOF.

2. The *kinematic state*: tracks velocities (or momenta). Specifying the kinematic state for a free point particle requires 6 independent parameters: one for each independent configuration coordinate, and one for the velocity along that coordinate; hence a free point particle has 6 kinematic DOF, and a system of \( n \) free point particles has \( 6n \) kinematic DOF.

3. The *dynamic state*: tracks energies determining the motion. For a given entity, there is typically at least one dynamic DOF per configuration DOF, tracking the kinetic energy associated with each position coordinate; in addition there may be dynamic DOF tracking internal or external contributions to the potential energy, as with vibrating systems or entities in a potential field. So, for example, specifying the dynamic state for a spring attached to a wall, having a single configuration DOF, requires two dynamic DOFs: one for the kinetic energy associated with the spring’s movement, and one for the potential energy of the spring.

The configuration, kinematic, and dynamic states are crucial to expressing the characteristic properties and behavior of many entities in a range of sciences; but other states (e.g., pertaining to quantum phenomena, in particular) might be relevant to an entity’s governing laws, and require corresponding DOF in order to be specified.

### 2.2 Reductions, restrictions, and eliminations in DOF

The DOF needed to characterize an entity may be reduced, restricted, or eliminated in certain circumstances, compared to those needed to characterize an entity when such circumstances are not in place. Let’s first get clear on the distinctions between reduction, restriction, and elimination in DOF, using some simple examples.\(^{13}\)

*Reduction in DOF.* One way in which a reduction in DOF may occur is in circumstances where constraints are in place. So, for example, a point particle constrained to move in a plane has 2 configuration DOF (and correspondingly fewer kinematic and dynamic DOF), rather than the 3 configuration DOF required to characterize a free

---

\(^{13}\)So far as I am aware, these distinctions in relations between DOF have not been previously explicitly flagged in the literature.
point particle. More generally, the “freezing” of the value of a previously independent parameter along a certain dimension of variation (associated with “holonomic” constraints) reduces the DOF needed to specify the associated characteristic states:

A system of \( N \) particles, free from constraints, has \( 3N \) independent coordinates or degrees of freedom. If there exist holonomic constraints, expressed in \( k \) equations in the form \( f(r_1, r_2, r_3, \ldots, t) = 0 \), then we may use these equations to eliminate \( k \) of the \( 3N \) coordinates, and we are left with \( 3N - k \) independent coordinates, and the system is said to have \( 3N - k \) degrees of freedom.\(^{14} \) (Goldstein et al. 2002, p. 12)

Notwithstanding Goldstein et al.’s talk of ‘elimination’, cases where a DOF receives a constant value as a result of the imposition of a constraint are really best seen as involving ‘reductions’, rather than ‘eliminations’, in DOF (I’ll discuss the latter cases shortly). In such cases (as with the systems discussed by Goldstein et al.), the laws governing an entity so constrained are still functionally dependent on the (now constant) value of the DOF; hence such constraints do not eliminate the DOF in question, but rather reduce it to a constant value.

Restrictions in DOF. The imposition of constraints may restrict rather than reduce the DOF needed to specify a given state when the constraints are not in place. So, for example, a point particle may be constrained, not to the plane, but to some region including and above the plane. Characterizing such a constrained particle will still require the same 3 configuration DOF as the corresponding free particle, but the values of one of the configuration DOF (and associated kinematic and dynamic DOF) will be restricted to taking on a subset of the nomologically possible values available to the unconstrained particle.

Cases of restriction in DOF are more like cases of reduction than elimination of DOF, in that, here again, the laws governing the constrained entity remain functionally dependent on values of the DOF.

Elimination in DOF. Sometimes the imposition of constraints eliminates DOF. So, for example, \( n \) free point particles, having \( 3n \) configuration DOF, might come to compose an entity whose properties and behavior can be characterized using relatively few

\(^{14} \)Here Goldstein et al. speak as though that the constrained system is the same system as the unconstrained system; for present purposes this should not be taken for granted, for reasons that will become clear down the line.
configuration DOF, not because certain of the DOF needed to characterize the unconstrained system are given a fixed value, but because the properties and behavior of the composed entity are functionally independent of these DOF (as when the electric field generated by a spherical conductor depends only on the configuration DOF of composing particles on its boundary).

As I’ll now discuss, each of these relations between DOF—reductions, restrictions, and eliminations—are associated with certain intuitively physically acceptable special science entities.

2.2.1 Rigid bodies and molecules

Structural composition involves constraints that can reduce, restrict, or eliminate the DOF needed to specify the configuration state (and/or states dependent on that state) of a composed entity $E$, relative to the DOF needed to characterize the system of its unconstrained composing entities $e_i$.

Consider first rigid bodies of the sort treated by classical mechanics, involving particles constrained to stand in rigid bonds. Recall that a system of 2 free point particles requires 6 configuration DOF. For a rigid body $E$ composed of two point particles constrained to be distance $r$ from each other, only 5 DOF are required to specify the system’s configuration state: 3 to specify the first particle’s location, and 2 to specify that of the second particle, which is effectively constrained to positions on the surface of a sphere of radius $r$ having the first particle at the center. Similarly, a system of $N$ such $E$ would have, not $6N$, but only $5N$ configuration DOF; were the $E$ to themselves become bonded, the resulting composed entity $E'$ would have some configuration DOF $< 5N$; and so on, up the ladder of structural complexity. Rigid bodies are thus illustrative of reductions in DOF.

Consider next entities of the sort treated by molecular physics. The constraints associated with a given molecular structure $E$ (involving bonds roughly analogous to springs) are nonrigid, hence compatible with the composing atoms’ occupying a range of position and momentum states. Such “variable” constraints lead to a restriction (rather than a reduction or elimination) in DOF needed to characterize $E$, relative to those needed to characterize the system of unconstrained atoms: certain values of certain DOF (in particular, the configuration DOF, and any DOF depending on these) that are nomological possibilities for the latter system are not nomological possibilities for
Molecules are thus illustrative of restrictions in DOF.

Consider next entities of the sort treated by electrostatics. As previously noted, the electric field generated by a system of \( n \) free charged point particles will functionally depend on all 3\( n \) of the system’s configuration DOF. If these particles come to compose a spherical conductor, however, the electric field fill functionally depend only on the configuration DOF of particles on the boundary of the sphere. Spherical conductors are thus illustrative of eliminations in DOF.

2.2.2 Statistical-mechanical aggregates

Consider next entities of the sort treated by statistical mechanics (SM)—say, an isolated gas \( E \) composed of large numbers of particles or molecules \( e_i \). One might think that, beyond the restrictions in DOF associated with the boundaries of the gas, an unstructured aggregate like \( E \) wouldn’t involve any reductions, restrictions, or eliminations in DOF: since \( E \) is an unstructured aggregate, shouldn’t it have the same DOF (along with associated possible values) as the system of unconstrained \( e_i \)? Moreover, the characteristic states of thermodynamic systems are often understood as requiring a large number of DOF for their specification, such that certain theorems of probability (e.g., the Central Limit Theorem) apply to such systems. So understood, however, the success of SM is something of a mystery. Recall that a system of free point particles has 3\( N \) configuration DOF, 6\( N \) kinetic DOF, and at least as many dynamic DOF; and these numbers will go up if the composing entities are spatially extended. In the systems with which SM is concerned, \( N \) is of the order of \( 10^{23} \) or greater, giving rise to a huge number of associated DOF. Nonetheless the properties and behavior of SM systems can be understood without paying any attention to all these DOF. How is this so?

The key lies in noting that, while not bonded, the \( e_i \) composing SM systems are interacting via exchanges of energy, and such interactions may not only restrict or reduce, but eliminate DOF. Here I refer to Batterman’s (1998) explanation of SM’s success in terms of the application of the renormalization group method to SM systems. This method is commonly used to model complex systems, whose behavior at critical points manifests considerable similarity across systems that are diverse with respect to both composition and motions of the composing elements. In particular, the method deter-
mines the stability of the functions (e.g., the Hamiltonians) expressing the influences guiding the system’s evolution. If a complex system $E$’s behavior is stable (evolves to the same state) under perturbations of these influences (reflecting different compositions and motions of the composing $e_i$) then certain features of the $e_i$ are thereby shown to be irrelevant to $E$’s evolution. There is a corresponding elimination of certain of the DOF needed to characterize states pertaining to $E$’s the behavior:

In effect, the renormalization group transformation eliminates those degrees of freedom (those microscopic details) which are inessential or irrelevant for characterizing the system’s dominant behavior at criticality. (Batterman 1998, p. 109; his emph.)

The renormalization group transformation also appropriately models the behavior of SM systems approaching equilibrium—unsurprisingly, since as with complex systems, SM systems exhibit similar behaviors across a wide range of composition and motions of their composing entities. The general moral follows:

This stability under perturbation demonstrates that certain facts about the microconstituents of the systems are individually largely irrelevant for the system’s behaviors [...]. (Batterman, p. 200)

To sum up: SM aggregates are thus illustrative of eliminations in DOF.

2.2.3 Quantum DOF in the classical limit

Elimination of quantum DOF is ubiquitous in the composition of special science entities, both structurally and non-structurally composed. In particular, the probabilistic nature of quantum trajectories becomes functionally irrelevant to the properties and behaviors of entities in the macroscopic limit.

DOF associated with the probabilistic nature of quantum trajectories cease to be relevant to the properties and behaviors of macrophenomena, because the probabilistic values of quantum mechanical observables average out to their mean values in the large-scale limit. This is how classical mechanics “emerges” from quantum mechanics, as per Messiah (1970, p. 215). Forster and Kryukov (2003, p. 1040) provide a useful explanation by analogy of how this occurs:

It may be surprising that deterministic laws can be deduced from a probabilistic theory such as quantum mechanics. Here, curve-fitting examples
provide a useful analogy. Suppose that one is interested in predicting the value of some variable $y$, which is a deterministic function of $x$, represented by some curve in the $x − y$ plane. The problem is that the observed values of $y$ fluctuate randomly above and below the curve according to a Gaussian (bell-shaped) distribution. Then for any fixed value of $x$, the value of $y$ on the curve is well estimated by the mean value of the observed $y$ values, and in the large sample limit, the curve emerges out of the noise by plotting the mean values of $y$ as a function of $x$.

To apply the analogy, consider $x$ and $y$ to be position and momentum, respectively, and the deterministic relation between them to be Newton’s laws of motion. Then it may be surprising to learn that Newton’s laws of motion emerge from QM as relations between the mean values of QM position and QM momentum. These deterministic relations are known as Ehrenfest’s equations. In contrast to curve fitting, the Heisenberg uncertainty relations tell us that the QM variances of position and momentum are not controllable and reducible without limit. Nevertheless, it is possible for both variances to become negligibly small relative to the background noise. This is the standard textbook account of how Newton’s laws of motion emerge from QM in the macroscopic limit.

Forster and Kryukov are explicit that probabilistic averaging as a generator of macro-laws is a method of “abstracting away from the messy details” of the underlying microphenomena; in other words, quantum DOF are eliminated in the classical limit. Hence macroscopic phenomena of the sort treated by classical mechanics are illustrative of eliminations in DOF.\footnote{As a referee noted, this line of thought is most straightforwardly supported against the background of an interpretation of QM on which the probabilities can be seen as, e.g., objective properties of particles to be at (e.g.) one location or another at the next instant (as on the Copenhagen interpretation). On some interpretations, it is less than clear that probabilistic variance will turn out to be fundamental DOF of the entities at issue. So, for example, on the Everettian interpretation, probabilities don’t show up in the formalism at all, and on the Bohmian interpretation the probabilities are merely epistemic. I am inclined to think that at least some of the available interpretations can be seen to involve elimination of quantum DOF in classical limit, but can’t enter into these issues here. For present purposes, it suffices to note that at least one interpretation is associated with elimination in DOF, and that in any case (as previously) there are clear cases of non-quantum elimination in DOF.}

### 2.3 $e_i$-level constraints and $e_i$-level determination

The above cases show that many structurally and non-structurally composed, intuitively physically acceptable special science entities $E$ (treated by molecular physics,
and statistical and classical mechanics) involve a reduction, restriction or elimination in the DOF needed to characterize them as being in certain states relevant to their properties and behavior, relative to the DOF needed to characterize the system of their unconstrained composing entities $e_i$ as being in those states.

Two additional features common to these special science entities are worth noting, for what follows.

First is that the holding of the constraints resulting in reductions, restrictions, or eliminations in DOF is a matter entirely of physical or physically acceptable processes. Such processes suffice to explain why sufficiently proximate atoms form certain atomic bonds; why atoms or molecules engage in the energetic interactions associated with SM ensembles; why quantum features cease to be relevant in the classical limit. More generally, for each of the special science entities $E$ at issue, the constraints on the $e_i$ associated with the latter’s composing $E$ are explicable using resources of the theory treating the $e_i$ (or using resources of some more fundamental theory, treating the constituents of the $e_i$). I’ll refer to such constraints as “$e_i$-level constraints”.

It may be that some more precise account of the notion of theoretical explication of some constraints can be given, in scientific or metaphysical terms. So, for example, perhaps it suffices for some constraints to be $e_i$-level that circumstances corresponding to the holding of the constraints are in the state space of some $e_j$ treated by the theory treating the $e_i$. Or perhaps an appeal to what is nomologically possible for entities in the theory treating the $e_i$ will do (namely, that it be nomologically possible that they exist in circumstances corresponding to the constraints). Beyond these brief remarks I won’t try to provide an account of theoretical explication of (in particular, $e_i$-level) constraints, since whatever the details it is in any case uncontroversial that the constraints whereby the entities composing our exemplar special science entities are themselves explicable in terms of physical or physically acceptable processes.\footnote{Thanks to two referees for pointing out the importance of attention to the physical explicable of the constraints, for my purposes.}

A second feature of each of the aforementioned special science entities $E$ is that all of their properties and behavior are completely determined by the properties and behavior of their composing $e_i$, when these stand in the relations relevant to their composing $E$.\footnote{Note that this feature does not in itself follow from $E$’s being composed by $e_i$ as a result of imposing $e_i$-level constraints. It might be, for example (as the British Emergentists thought), that some entities $E$, composed in a physically acceptable fashion from physically acceptable entities, have properties or behaviors that are not themselves physically acceptable.}
So, for example, the properties and behavior of molecules are completely determined by the properties and behavior of their composing atoms; the properties and behavior of SM ensembles are completely determined by the properties and behavior of their composing atoms or molecules; the properties and behavior of mechanical systems in the classical limit are completely determined by the properties and behavior of their composing quantum entities. People disagree about the metaphysical ground for this determination; in particular, reductive and non-reductive physicalists disagree about whether it is grounded in identity, or rather in some weaker but still very intimate relation. Whether there is room for the latter sort of view is, of course, what is primarily at issue in this paper. So again I won’t antecedently come down on any particular account of determination, since in any case all parties agree that all of the law-governed properties and behavior of the composed entities $E$ at issue are completely determined by law-governed properties and behavior of their composing $e_i$, when these stand in the relations relevant to their composing $E$. I’ll sometimes call such determination ‘$e_i$-level determination’.

3 DOF and weak emergence

I’ll now argue that eliminations in DOF, in particular, provide a basis for weak emergence of the sort vindicating NRP. In fact, many of the features of the entities at issue (satisfying both Physicalism and Non-reduction) are equally features of entities having reduced or restricted DOF; however, as I’ll later discuss (§6), there is a principled route for not taking reductions or restrictions in DOF as indicative of ontological emergence. Since not everyone may want to take this route, I’ll keep entities associated with reductions and restrictions in DOF on the table, and flag the choice point down the line.

3.1 Weak ontological emergence

Taking the case studies as a guide, I propose the following thesis:

*Weak ontological emergence* (DOF): An entity $E$ is weakly emergent from some entities $e_i$ if

1. $E$ is composed by the $e_i$, as a result of imposing some constraint(s) on the $e_i$,
2. For some characteristic state $S$ of $E$: at least one of the DOF required to characterize the system of unconstrained $e_i$ as being in $S$ is eliminated from the DOF required to characterize $E$ as being in $S$.

3. For every characteristic state $S$ of $E$: Every reduction, restriction, or elimination in the DOF needed to characterize $E$ as being in $S$ is associated with $e_i$-level constraints;

4. The law-governed properties and behavior of $E$ are completely determined by the law-governed properties and behavior of the $e_i$, when the $e_i$ stand in the relations relevant to their composing $E$.

Several clarifications concerning *Weak ontological emergence* and its applications are in order:

1. I assume only that the conditions above are sufficient, not necessary, for weak emergence of the sort that (I will presently argue) vindicates NRP.

2. The application of *Weak ontological emergence* assumes that $E$ exists, since that a scientific treatment involves an elimination in DOF may not entail the coming to be (much less weak emergence) of any entity, but may rather indicate a pragmatic technical manoeuvre.\(^\text{18}\) This assumption is acceptable, for my goal is to distinguish NRP not from eliminativism, but rather from reductive physicalism (on which all existing entities $E$ are ontologically reducible to physical entities) and emergentism (on which some existing entities $E$ are robustly emergent from physical entities).

3. Again, the strategy of gaining insight into the ontological status of special science entities by attention to the (relations between sets of) DOF needed to specify their characteristic states assumes that we can, however fallibly, give a broadly realist interpretation to scientific theories.

4. That some special science entities satisfy *Weak ontological emergence* is compatible with the ontological reducibility of other special science entities. So, for example, in cases where a given special science entity $E$ satisfies conditions (1), (3), and (4) but not (2), on grounds that the constraints at issue only reduce or restrict the DOF needed to characterize $E$, there is a case to be made (again,\(^\text{18}\) As with the elimination of DOF involved in representing the generalized three-body problem in solvable form.

\(^{18}\)
see §6) that \( E \) is ontologically reducible to its composing \( e_i \). Another route to reduction might occur if a composed special science entity \( E \) satisfies conditions (1), (3), and (4) but not (2), on grounds of requiring, for each of its characterizing states, the same DOF and associated ranges of possible values as the system of its composing entities \( e_i \). Such a case is modeled by entities \( e_i \) that only exist under certain compositional constraints—perhaps quarks (which exist not in isolation, but only in twos or threes) are such \( e_i \). (In such a case it might not be appropriate to see constraints being imposed on the \( e_i \); rather, the constraints were always or essentially in place.) For all Weak ontological emergence says, there is no barrier to an entity \( E \) (e.g., a proton) being identical to the relational entity consisting of its composing \( e_i \) in (always or essentially constrained) relation.\(^{19}\)

4 The physical acceptability of weakly emergent entities

The composed special science entities inspiring the above account of weak ontological emergence are uncontroversially intuitively physically acceptable. In this section I’ll argue that taking such entities to satisfy Weak ontological emergence accommodates and justifies this intuitive judgement.\(^{20}\)

4.1 Eliminations in DOF and “theory extraction”

Ramsey (1995) suggests that eliminations in DOF signal that one theory has been “extracted” from another:

Theoretical scientists must often eliminate degrees of freedom from analytically or computationally intractable equations. They employ a variety of mathematical techniques and physical assumptions to transform such equations into tractable theoretical models with clear, testable, consequences. In other words, they extract a specific model from a more general model type. (p. 1)

\(^{19}\) Thanks to Noa Latham for discussion of this issue.

\(^{20}\) Those who are primarily interested in seeing how physically acceptable special science entities can satisfy Non-reduction can skip to §5 without undue loss of continuity.
Ramsey notes that in cases of theory extraction, “scientists self-consciously develop the model by utilizing only a subset of an antecedently accepted theory’s resources” (p. 2); relatedly, he cites Sklar (1967, p. 110) as noting that an extracted theory is “properly speaking, only a fragment of the reducing, developable from it by mere deductive reasoning”.

Ramsey’s remarks provide a useful starting point for thinking about the relations between special and more fundamental sciences, when constraints imposed on the more fundamental $e_i$ give rise to a composed special science entity $E$. For the cases considered above, involving reductions, restrictions, or eliminations in DOF, it is intuitively plausible to see the associated special science as a special case of the more fundamental science, reflecting the latter theory as restrictedly applied to circumstances in which the constraints are in place. However, the focus of Ramsey’s (and in context, Sklar’s) remarks is on ‘homogeneous’ extractions, in which (following Nagel’s 1961 terminology) the vocabulary of the extracted theory is contained in that of the more general theory: “transformation reductions appear to be straightforward homogeneous reductions” (p. 2). By way of contrast, the special science entities that are our concern are typically treated by sciences (molecular physics, and statistical and classical mechanics) with vocabularies different from those treating their composing entities. Does it make sense to see the special sciences treating these entities as extracted from the more fundamental sciences, hence as being “properly speaking, only a fragment of the reducing, developable from it by mere deductive reasoning”?

The most straightforward way of establishing that the reductions, restrictions, and eliminations in DOF at issue in these cases also involve theory extractions would be to motivate the availability of appropriate bridge laws, connecting the inhomogeneous vocabularies; however, in the present dialectical context we need to be careful about how such laws are understood. Bridge laws expressing mere nomological coextension are intuitively too weak to support the claim of extraction. On the other hand, bridge laws expressing identities support the claim of extraction (or inter-theoretic reduction, in the relevant sense; see Sklar 1967, p. 120); but that such identities are always appropriate is precisely what the NRPist denies.

Luckily, we don’t need to come down on what metaphysical relation(s) are or are not expressed in the inhomogeneous bridge laws at issue to establish that, for special sciences treating weakly ontologically emergent entities, relations strong enough to support inhomogeneous theory extraction must be in principle available.
For simplicity, consider a relatively fundamental theory $T$ treating of some $e_i$, and a special science $T'$ treating a single entity $E$ composed by imposing some constraints on the $e_i$; the following result will generalize. There are two reasons why bridge laws of the sort at issue in theory extraction might not be available to connect the vocabularies of $T$ and $T'$. First would be if $E$ had any law-governed properties or behavior not completely determined by the law-governed properties or behavior of the $e_i$, thus requiring resources beyond those of $T$; second would be if the imposition of the constraints on the $e_i$ relevant to their composing $E$ required resources beyond those of $T$. But if $E$ satisfies \textit{Weak ontological emergence}, the first possibility is ruled out by condition (4) ($e_i$-level determination) and the second by condition (3) ($e_i$-level constraints).

Moreover, when $E$ is weakly emergent, $T'$ is appropriately seen as a ‘fragment’ of $T$: in treating the $e_i$ both when they stand in the relations associated with the $e_i$-level constraints, and when they do not stand in these relations, $T$ has resources that $T'$ doesn’t have. Hence $T'$ utilizes a proper subset of the resources of $T$. Coupled with the in-principle availability of appropriate bridge laws connecting the vocabularies of $T$ and $T'$, this result indicates that it makes sense to see $T'$ as extracted from $T$, in being “properly speaking, only a fragment of the reducing, developable from it by mere deductive reasoning”.

Generalizing, we may safely assume that the special sciences treating the composed entities $E$ (satisfying \textit{Weak ontological emergence}) that are our concern are appropriately seen as extracted from the more fundamental sciences treating their composing $e_i$, such that the laws of the special science (expressing, in particular, the properties and behavior of $E$) are deducible consequences of the laws of the more fundamental science (expressing, in particular, the properties and behavior of the $e_i$).

I’ll now use this result to argue that the special science entities $E$ that are our concern are, as is intuitively the case, physically acceptable.

### 4.2 An argument by induction for physical acceptability

Plausibly, special sciences treating (only) uncontroversially physically acceptable entities are extracted either from fundamental physics, or from a special science extracted from fundamental physics, or from a special science extracted from a special science.

---

21 Whether we have the semantic or other analytic resources to explicitly engage in such deductive reasoning is, of course, besides the metaphysical point.
extracted from fundamental physics, . . . Hence we may establish the physical accept-
ability of entities in these sciences by induction, showing first, that the entities treated
by fundamental physics are physically acceptable (the base step); second, that entities
$E$ treated by a special science extracted from a science treating (only) of physically
acceptable entities are physically acceptable (the inductive step).

The base step is easy, since on the working conception of the physical the entities
treated by fundamental physics are physical,\footnote{Assuming, as is plausible, that none of these entities is fundamentally mental (see note 4).} hence physically acceptable.

Key to establishing the inductive step is that the extracted theory has a proper
subset of the resources of the more fundamental theory, such that every law in the
extracted theory is a deductive consequence of the more fundamental theory.

Let us now suppose that a special science treating an entity $E$ is extracted from a
science treating (only) physically acceptable entities. Is $E$ physically acceptable—that
is, nothing over and above physical entities? On the standard accounts of nothing over
and aboveness (and one non-standard variation), the answer is yes:

- On entailment accounts, $E$ is nothing over and above the $e_i$ if sentences expressing
the properties and behavior of $E$ are entailed (possibly with the help of appropriate
bridge laws, as above) by sentences expressing the properties and behavior of the $e_i$.\footnote{See, e.g., Nagel 1961 and Kirk 2001.} $E$ satisfies this account: since $E$ is treated by a theory extracted from
the theory treating the $e_i$, every sentence expressing the properties and behavior
of $E$ is entailed (possibly with the help of appropriate bridge laws) by a sentence
expressing the properties and behavior of the $e_i$.

- On supervenience-based accounts, $E$ is nothing over and above the $e_i$ if there
could be no change in the properties or behavior of $E$ without a change in the
properties or behavior of the $e_i$.\footnote{See, e.g., Davidson 1970, van Cleve 1990, Chalmers 1996, and Stoljar 2000. Here the strength of
the modality at issue is metaphysical, not nomological (assuming there is a difference). My own view
is that supervenience even with metaphysical necessity is not sufficient for nothing over and aboveness
(see Wilson 2005).} $E$ satisfies this account, for suppose not. Then
there could be a change in the properties or behavior of $E$—say, $E$ is initially
$P$ and later comes to be $\neg P$—without a change in the properties or behavior
of the $e_i$. But as above, in cases of theory extraction, sentences expressing the
properties or behavior of $E$ are all entailed (possibly with the help of appropriate
bridge laws) by sentences expressing the properties and behavior of the $e_i$. This last, when combined with the supposition of $E$’s failure of supervenience, requires that there be some sentence $S$ expressing the properties and behavior of the $e_i$ such that $S$ (along with any needed bridge laws) entails ‘$E$ is $P$’, and $S$ (along with any needed bridge laws) entails ‘$E$ is not $P$’. But if so, the theory of the $e_i$ is inconsistent; hence the supposition of $E$’s failure of supervenience should be rejected.

- On “new causal powers” accounts, $E$ is nothing over and above the $e_i$ if every causal power of $E$ is identical to a causal power of the $e_i$ (when they stand in the relations relevant to their composing $E$). $E$ satisfies this account, since when $E$ is treated by a theory extracted from a theory of the $e_i$, $E$ does nothing that isn’t done by its composing $e_i$ (when, in particular, they stand in the relations relevant to their composing $E$); hence every causal power of $E$ is identical to a causal power of the system of composing $e_i$.

- On a non-standard variation of the previous account, $E$ is nothing over and above some other entities $e_i$, relative to a set of fundamental interactions $F$, if every causal power of $E$ is identical with a causal power of the $e_i$ grounded only in interactions in $F$. For let $F$ be the set of interactions needed to ground the causal powers of the $e_i$, as per the more fundamental theory. Since $E$ is treated by a theory whose resources are a proper subset of this more fundamental theory, every causal power of $E$ is identical to a causal power of the composing $e_i$ that is grounded only in the fundamental interactions in $F$.

Safely, $E$ is nothing over and above the $e_i$. But the $e_i$ are nothing over and above physical entities, by hypothesis. Now, on each of the above accounts of nothing over and aboveness, this feature is transitive (an easy exercise). Then: since $E$ is nothing over and above entities that are nothing over and above physical entities, $E$ is nothing over and above physical entities. So $E$ is physically acceptable.

This establishes the inductive step. We may conclude that when a given special science is extracted from more fundamental theories ultimately extracted from fundamental physics, the associated special science entities are physically acceptable, hence

---


26See Wilson 2002.
conform to Physicalism.

5 The ontological irreducibility of weakly emergent entities

I turn next to establishing that entities satisfying Weak ontological emergence (that is: weakly emergent entities) plausibly satisfy Non-reduction. I'll first pitch my arguments against the two main specific objections to ontological irreducibility: from theoretical deducibility (§5.1) and from potential causal overdetermination (§5.2). I'll then consider whether general considerations of ontological parsimony support a reductive view of the entities at issue (§5.3). In each case my response on behalf of irreducibility appeals to the metaphysical implications of the associated eliminations in DOF.

5.1 The objection from theoretical deducibility

In cases where an extracted theory treats weakly emergent entities, the laws of the extracted theory are, as above, deducible consequences of the laws of the more fundamental theory. Does the theoretical deducibility of laws in sciences treating weakly emergent entities $E$ indicate that such $E$ are ontologically reducible to their composing $e_i$? For short: does theoretical deducibility entail ontological reducibility?

An affirmative answer seems initially plausible, and has been commonly endorsed. Consider these remarks by Klee (citing Nagel), directed against an account of emergence (presumed to involve irreducibility) on which emergent entities and laws simply involve new relational structures:

[I]n what sense are these new regularities emergent? To be sure, they may be regularities and structures of a type not found on lower-levels of organization, but it has seemed to some (Nagel 1961, pp. 367–74) that this fact by itself would not justify the label of “emergent” if they had been predictable on the basis of a thorough understanding of those lower-levels of organization. If the new relational structure which grounds the new regularities could have been predicted on such a basis, then the new regularities could have been predicted and the force of any emergence claim, at least partially, compromised. (Klee 1984, p. 46)
Indeed, it might seem practically definitional that theoretical deducibility entails ontological reducibility:

Reductionism is sometimes expressed as the thesis that the laws of the non-physical sciences can be deduced from those of the physical sciences together with certain bridging generalizations [...] (Owens 1989, p. 63)

Such considerations lead to a seeming dilemma for the NRPist, directed against the core claim (applied to the cases at issue) that Physicalism and Non-reduction are compatible. As above, the constraints entering into the composition of our target special science entities are plausibly \(e_i\)-level constraints—that is, constraints explicable using resources of the theory treating the \(e_i\);\(^{27}\) and this feature of the constraints was crucial to establishing the physical acceptability of the entities at issue. Indeed, unless the constraints are \(e_i\)-level, one might well be suspicious of the NRPist’s claim that the composed entities are really nothing over and above their composed \(e_i\) (in conformity to Physicalism. But if the constraints are \(e_i\)-level, one might naturally wonder, why can’t the associated \(e_i\)-level relations enter, one way or another, into an ontological as well as a theoretical reduction of \(E\) to its composing \(e_i\)? Hence the dilemma: the NRPist can’t, it seems, have their physical acceptability and their irreducibility too.\(^{28}\)

5.1.1 The response from different DOF

For weakly emergent entities, however, theoretical deducibility (ultimately establishing the physical acceptability of our target entities) is compatible with ontological irreducibility.

For simplicity let’s assume that \(E\) is a weakly emergent entity composed of physical \(e_i\). If \(E\) is to be ontologically reducible to the \(e_i\) (contra Non-reduction), then \(E\) must be identical either to

(i) a system consisting of the jointly existing \(e_i\),\(^{29}\)

(ii) a relational entity consisting of the \(e_i\) standing in \(e_i\)-level relations, or

\(^{27}\)Or using resources of some more fundamental theory, treating the constituents of the \(e_i\); I won’t carry this qualification through in presenting the dilemma.

\(^{28}\)Thanks to a referee for this apt expression of the present concern facing the NRPist.

\(^{29}\)I assume that it is not a live possibility that \(E\) is identical to a system consisting of a proper subset of jointly existing \(e_i\), given that all the \(e_i\) enter into composing \(E\).
(iii) a relational entity consisting in a boolean or mereological combination of the entities at issue in (i) and (ii).\textsuperscript{30}

Since \(E\) is weakly emergent, there is some characteristic state \(S\) such that characterizing \(E\) as being in this state requires strictly fewer DOF than are required to characterize the unconstrained system of \(e_i\) as being in \(S\). Hence a necessary condition on \(E\)'s being identical with an entity of the type at issue in (i)–(iii) is that the DOF required to characterize the candidate reducing entity as being in \(S\) are similarly eliminated, relative to the unconstrained system. But as I'll now argue, characterizing each of the candidate reducing entities at issue in (i)–(iii) require all the DOF needed to characterize the unconstrained system of \(e_i\), for any state that might be at issue.

First, consider the \(e_i\) understood as (merely) jointly existing (as per (i)). Such a system of \(e_i\) is not subject to any constraints; hence for any state, characterizing this system will require the same DOF as are required to characterize the system of unconstrained \(e_i\). Since there is at least one state for which characterizing \(E\) requires fewer DOF than are required to characterize the system of unconstrained \(e_i\), \(E\) is not identical to the system consisting of (merely) jointly existing \(e_i\).

Second, consider the relational entity consisting of the \(e_i\) standing in certain \(e_r\)-level relations. The relational entities that are the most likely candidates for identity with \(E\) are those that realize \(E\); so let’s focus on such a realizing entity \(e_r\).\textsuperscript{31} Notwithstanding that \(e_r\) can realize a constrained entity (namely, \(E\)), \(e_r\) is not itself appropriately seen as constrained—even throwing the holding of the constraints into the mix of \(e_r\)-level relations at issue in \(e_r\) (as per the aforenoted dilemma for the NRPist).

Why not? Because the laws governing entities consisting of the \(e_i\) standing in \(e_r\)-level relations (including \(e_r\)) are, unlike the laws governing \(E\), compatible with the constraints being relaxed; hence characterizing \(e_r\) as entering into these laws requires all the DOF associated with the unconstrained system of \(e_i\). Consider, for example, a relational quantum entity \(e_r\) realizing a constrained macro-system. Such a quantum \(e_r\)

\textsuperscript{30}Suggestions that the reducing entity might be of boolean or mereological form are typically aimed at accommodating the seeming multiple realizability of \(E\), with the disjuncts or parts being individual realizers of \(E\). On a separate note: here I am glossing the question of whether \(E\) or any of its candidate reducing entities are to be understood along perdurantist or endurantist lines. The resources in either (ii) or (iii) will accommodate either view, though by default I will speak in endurantist terms.

\textsuperscript{31}Here we assume that \(E\) has only one realizer; in cases of multiple realizability the candidate reducing entity is typically taken to be a disjunctive (less commonly: mereological) entity whose disjuncts (parts) are the multiple realizers; as previously, such entities are treated under type (iii).
may evolve, as per its governing quantum laws, into a differently constrained or unconstrained system of quantum $e_i$; hence the appropriate characterization of $e_r$ as entering into its governing system of laws will require all the DOF required to characterize its evolution into a potentially unconstrained system of quantum $e_i$. So even allowing that the relations at issue in $e_r$ include those corresponding to $e_i$-level constraints, characterizing $e_r$ as being in any given characteristic state will require all the DOF required to characterize the unconstrained system of $e_i$ (into which $e_r$ can potentially evolve, as per its governing laws). Since there is at least one state for which characterizing $E$ requires fewer DOF than are required to characterize the system of unconstrained $e_i$, $E$ is not identical to $e_r$, or any such relational entity.\footnote{As mentioned previously, there is no bar to a composed entity $E$’s being identical to a relational realizing entity, so long as no elimination in DOF is at issue; but then $E$ does not satisfy \textit{Weak ontological emergence}.}

Third, consider a relational entity consisting in a boolean (presumably disjunctive or conjunctive) or mereological combination of entities of the sort at issue in (i) or (ii). Again, for $E$ to be identical to any such reducing entity, characterizing the latter must require the same DOF as characterizing $E$. So let’s consider the options.

To start, a disjunctive entity is one whose occurrence consists in any one of its disjunct entity’s occurring. Hence for any state, characterizing a disjunctive entity as being in that state will require all the DOF required to characterize any one of the disjunct entities as being in that state. Moreover (drawing on previous results), each of the disjunct entities, being of type (i) or (ii), will require for its characterization all the DOF required to characterize the system of unconstrained $e_i$, for any state. So the DOF needed to characterize a disjunctive relational entity consisting of a disjunction of entities of type (i) or (ii) will not be eliminated relative to those needed to characterize the system of unconstrained $e_i$, for any characteristic state; hence $E$ is not identical to any such disjunctive entity.

What about conjunctive relational entities? A conjunctive entity is one whose occurrence consists in the joint holding of each of its conjunct entities.\footnote{Conjunctive entities whose conjuncts are interacting by standing in $e_i$-level relations will fall under type (ii), and hence fail to be identical to $E$, for reasons previously stated.} Hence for any state, characterizing a conjunctive entity as being in that state will require all the DOF required to characterize any one of the conjunct entities as being in that state. Moreover (drawing on previous results), each of the conjunct entities, being of type (i) or (ii), will require for its characterization all the DOF required to characterize the system of unconstrained $e_i$, for any state.

\begin{center}
23
\end{center}
of unconstrained $e_i$, for any characteristic state at issue. So the DOF needed to characterize a conjunctive entity consisting of a conjunction of entities of type (i) or (ii) will not be eliminated relative to those needed to characterize the system of unconstrained $e_i$, for any characteristic state; hence $E$ is not identical to any such conjunctive entity.

Finally, what about mereological combinations? Mereological wholes are identified with the mere joint holding of their parts; hence characterizing the whole will require all the DOF required to characterize each of the parts. Here the parts at issue are entities of type (i) or (ii); hence characterizing the whole will require all the DOF as are needed to characterize entities of type (i) or (ii). But (drawing on previous results), each entity of type (i) or (ii) will require for its characterization all the DOF required to characterize the system of unconstrained $e_i$. So the DOF needed to characterize a mereological combination will not be eliminated relative to those needed to characterize the system of unconstrained $e_i$, for any characteristic state; hence $E$ is not identical to any such mereological combination.

That exhausts the available types of candidates to which our target special science entities might be reduced. I conclude that considerations of DOF indicate that the objection from theoretical deducibility to Non-reduction does not go through. In particular, attention to the metaphysical implications of the eliminations of DOF at issue in weak ontological emergence indicates that weakly emergent entities $E$ are ontologically irreducible to their composing $e_i$, even though, in being treated by a science extracted from one treating the $e_i$, $E$’s properties and behavior are all deducible from the properties and behavior of the $e_i$.

5.2 The objection from causal overdetermination

The most substantive objection to Non-reduction as compatible with Physicalism is of the sort pressed in Kim 1989 and 1993a. Kim’s concern may be seen as developing another dilemma for the NRPIst, which highlights a seeming untoward causal consequence of the view; here I formulate Kim’s concern as directed at our target special science entities. Again, for simplicity assume that the $e_i$ composing such $E$ are physical.

As Kim notes, the reality of a broadly scientific entity plausibly requires (as per “Alexander’s Dictum”) that it has (or bestows; I won’t carry this qualifier through) causal powers. So if a special science entity $E$, composed of some physical $e_i$, is to be real, it must have causal powers. Now, as above, $E$ is treated by a science extracted
from one treating its composing \( e_i \), and hence doesn’t do anything the \( e_i \) (or associated relational entities; I won’t carry this qualification through) don’t do. If this result holds as a result of \( E \)’s powers being numerically identical with those of its composing \( e_i \), then \( E \)’s physical acceptability is guaranteed; but then \( E \) would seem to be reducible to the \( e_i \). On the other hand, reduction can be avoided if at least some of \( E \)’s powers are irreducible to those of its composing \( e_i \), at least (against the continuing assumption of theory extraction) in the sense of being token (if not type) distinct; but then it seems that \( E \) will be in position to independently cause certain of the same effects caused by its composing \( e_i \), in such a way as to induce an implausible overdetermination of these effects. Here, then, the dilemma for the NRPIst is that satisfaction of Physicalism requires either rejection of Non-reduction or acceptance of an unsatisfactory causal overdetermination.

5.2.1 The response from the proper subset strategy

The above line of thought fails, however, to take into account what I call the “proper subset strategy.” Suppose that every causal power of \( E \) is identical with a causal power of its composing \( e_i \) (or associated relational entities, . . . ), yet the set of causal powers of \( E \) is a proper subset of the set associated with any of its composing \( e_i \). Then the reality of \( E \) can be gained (in virtue of \( E \) having a distinctive set of causal powers) while avoiding overdetermination (in virtue of each causal power of \( E \) being identical to a causal power of the \( e_i \) (or associated relational entities).

Of course, implementing the strategy requires that it be plausible that \( E \) does, in fact, have a proper subset of the causal powers of the \( e_i \) (or associated relational entities). The usual way of establishing this appeals to \( E \)’s multiple realizability. But \( E \)’s satisfaction of Weak ontological emergence suggests a means of doing this even if \( E \) is only single realized. In what follows I will focus on such a case, where \( E \) is singly realized by a relational entity \( e_r \).

\( E \), being weakly emergent, is treated by a theory extracted from a more fundamental theory treating of its composing \( e_i \), as a result of certain constraints being imposed on the latter. The laws of the extracted theory express what happens when the \( e_i \) stand in

---

34 See Wilson 1999 for details on how a wide variety of NRP accounts implement this strategy, explicitly or implicitly.
35 See, e.g., Shoemaker 1999: the general idea is that \( E \)’s causal powers are those in the intersection of the sets of causal powers of \( E \)’s realizers.
relations associated with the $e_i$-level constraints, and the laws in the more fundamental
theory express what happens when the $e_i$ stand both in these and in other relations
not associated with the constraints. For example, the laws of molecular physics express
what happens in circumstances conducive to the existence of molecules, and the laws
of atomic physics express what happens in these as well as in other circumstances—
involving, say, energies or temperatures too high for molecules to exist.

What does this mean for what causal powers should be assigned to $E$? Plausibly,
what causal powers an entity has are a matter of what it can do. And plausibly, the
sciences are in the business of expressing what the entities they treat can do. It follows
that, plausibly, what causal powers an entity has are expressed by the laws in the
science treating it.

So again consider $E$ and the relational entity $e_r$ that singly realizes it. Given that
what causal powers an entity has are expressed by the laws in the science treating
it, the causal powers of $E$ are those expressed by the laws in the extracted theory
treating $E$, while the causal powers of $e_r$ are those expressed by the laws in the more
fundamental theory treating the $e_i$ (and any associated relational entities). It follows
that $E$ has a proper subset of the causal powers had by $e_r$. For example, suppose $e_r$ is a
quantum relational entity, and $E$ is a macro-entity singly realized by $e_r$. Then the causal
powers of $E$ include all those powers to produce, either directly or indirectly, effects
that can occur in the constrained circumstances in which the quanta form macroscopic
entities (in other words: in the macroscopic limit). The realizing entity $e_r$ has all
these causal powers, and in addition has all those powers to produce, either directly or
indirectly, effects that can occur in circumstances that are not so constrained, and in
which quantum physics is operative—for example, effects occurring in circumstances
involving temperatures or energies in which atoms, but not molecules, can exist. Hence
$E$ has only a proper subset of the causal powers of $e_r$.\(^{36}\)

The same will be true, of course, for each of $E$’s realizers, if there are more than

\(^{36}\)Note that the argument here does not require that $e_r$ be able to exist without $E$’s existing: for
$e_r$ to have causal powers to bring about effects in circumstances not permitted by the constraints on
$E$ only requires that $e_r$ be connected by (quantum) law to goings-on that can exist in such relatively
unconstrained circumstances. The realizing entity $e_r$ is so connected; $E$ isn’t; hence $e_r$ has more causal
powers than $E$. If $e_r$ can exist in circumstances besides those in which $E$ can exist, that would provide
another way in which $e_r$ can do things that $E$ cannot do; such a state of affairs would violate the
supervenience of $E$ on (just) $e_r$ (as Justin Tiehen noted), but this doesn’t pose any deep problem for
supervenience claims, since the constraints can be built into the supervenience base (which is not to
say that we should build the constraints into $e_r$!).

26
one: every causal power of $E$ will be identical to a causal power of the entity that realizes $E$ on a given occasion, thus avoiding overdetermination; while the set of $E$’s causal powers will be distinct from the sets of each of $E$’s realizers, thus preventing $E$’s ontological reducibility to any such realizing entities. As for the remaining entities at issue in (i)–(iii): it’s clear that $E$ won’t have the same causal powers as any of these, so neither reduction nor overdetermination are live threats.

I conclude that considerations of DOF indicate that the NRPist is in a position to implement the proper subset strategy against the Kim-style objection from causal overdetermination, in service of Non-reduction.

5.3 The objection from Ockham’s razor

The previous objections were targeted against specific features of special science connections (deducibility, shared causal powers); my responses to these may be seen, in combination, as appealing to the metaphysical implications of eliminations in DOF associated with certain composed physically acceptable entities $E$ as making room for such $E$ to be ontologically irreducible, without inducing causal overdetermination. A remaining gambit for the reductionist appeals to Ockham’s razor, which counsels against positing unneeded entities. In being weakly emergent (hence treated by a theory extracted from a theory of the $e_i$), $E$ doesn’t do anything that the unconstrained $e_i$ (or associated relational entities) don’t do; but then (even granting that considerations of deducibility or overdetermination don’t force the issue of reduction) isn’t $E$ precisely the sort of posit that should be shaved away?

5.3.1 The response from ontological irrelevance

The NRPist may respond that there is another way to apply Ockham’s razor, again suggested by attention to DOF. In particular, why not see Ockham’s razor as cutting against the proposed ontological reduction, on grounds that an ontological characterization of a given entity should not involve unnecessary details? Yet if we identify $E$ with any of the candidate reducing entities above, then this is what we do; for $E$’s ontological characterization will thereby be saddled with details concerning the $e_i$ that the eliminations in DOF at issue in Weak ontological emergence show are plainly irrelevant to the law-governed properties and behavior of $E$. As such, the NRPist may reasonably
maintain, these details should be left out of \( E \)'s ontological characterization, and the reductionist's suggestion rejected.

It may be that ontological reductionists have thought that there is a necessity for giving \( E \) a reductive ontological characterization, for only this will guarantee \( E \)'s physical acceptability—and better an ontologically reductive physicalist than no physicalist at all. But as per §3, an entity \( E \) satisfying \textit{Weak ontological emergence} is physically acceptable if its composing \( e_i \) are; and the arguments to this effect were neutral on whether \( E \) was ontologically reducible. Hence the NRPist needn’t accept ontological reducibility as the price of their physicalism.

5.3.2 The response from explanatory relevance

The above appeal to Ockham’s razor in service of ontological irreducibility (such that an entity’s ontological characterization should not involve unnecessary details) is principled; but so is the reductionist’s appeal (such that one should not posit unnecessary entities in explanation of a given phenomenon). Such a standoff is sufficient for present purposes of defending NRP from the objection from Ockham’s razor, since the aim is not to push the ontological reductionist off their horse, but rather to give the NRPist a principled way to stay on their own.

We can say more, however, for considerations of explanatory relevance positively support the NRPist’s implementation of Ockham’s razor over the ontological reductionist’s. On a plausible view of explanation (Garfinkel 1981, Batterman 2002, Woodward and Hitchcock 2003, Strevens 2004), a pervasive and important feature of good explanations is that they don’t say too much. For example, in explaining the properties and behavior of a spherical conductor or an unstructured SM aggregate, one should cite only features that make a difference to the properties and behavior in question, omitting any features (such as the exact positions of the composing entities) that do not make a difference. This feature of good explanations itself needs explaining: Why does it make sense, as it so often does, to ignore details for explanatory purposes? That what is being explained involves entities whose ontological characterization omits irrelevant details, as reflected in the associated elimination in DOF, allows a straightforward answer, that moreover provides an ontological ground for our epistemology—a desirable result for the sciences, at least.\(^{37}\) The ontological reductionist, by way of contrast, has

\(^{37}\)Thanks to Michael Strevens for bringing this advantage to my attention.
no obvious explanation for explanatory relevance, much less one that provides a natural ontological ground for the associated epistemology.

6 The limits of ontological irreducibility

Weak ontological emergence, as I have formulated it here, takes eliminations in DOF (characteristic both of structured entities in the macroscopic limit, and unstructured SM aggregates) to be sufficient for ontological irreducibility. As anticipated previously, however, many of the features of entities whose composition involves an elimination in DOF are shared by entities whose composition involves a reduction or restriction in DOF. A remaining question is then: do the arguments I have given for irreducibility straightforwardly extend to the latter cases? If so, then many other special science entities would also turn out to be weakly emergent—too many, perhaps. For example, if reductions or restrictions in DOF also support irreducibility, then rigid bodies and molecules, respectively, would turn out to be ontologically irreducible to the relational entities that compose them. One might reasonably be concerned about such a result, for these sorts of cases seem to be paradigmatic of entities that are ontologically reducible.38

There is a principled reason, however, to resist treating cases of reductions and restrictions in DOF as on a par with cases of eliminations in DOF, supposing one is so inclined to do so. Here the key lies in the fact that eliminations of DOF, unlike mere reductions or restrictions in DOF, completely eliminate functional dependence of the properties and behavior of the composed entity on the parameter at issue. As previously noted (§2.2), reductions and restrictions in DOF do not eliminate this dependence, but rather reduce it to a single value or to a restricted range of values. This gives the reductionist room to manoeuvre. In such cases, it is less clear that the composed entities at issue cannot be identified with one or other of the candidate reducing entities of the types in (i)–(iii)—after all, in such cases the composed entity does, strictly speaking, require the same parameters for its characterization as the system of unconstrained composing $e_i$. One might reasonably maintain, then, that reductions or restrictions in DOF do not have the same ontological import as eliminations in DOF. Similarly, in cases of mere reduction or restriction in DOF, the standoff concerning the correct appli-

---

38That some special science entities are ontologically reducible to physical entities (in particular) is, of course, compatible with NRP, for the NRPIst claims only that some broadly scientific entities satisfy both Physicalism and Non-reduction.
cation of Ockham’s razor may break in favor of the reductionist, with the reductionist reasonably maintaining that the parsimony gained by identification is worth admitting some small amount of irrelevancy (associated with identifying the special science entity at issue with one whose DOF can take on values not allowed by the constraints) in the composed entity’s ontological characterization.

7 Concluding remarks

Eliminations in DOF characterize many special science entities, including structured entities in the macroscopic limit, and unstructured SM aggregates. Here I have argued that such eliminations in DOF provide a basis, via Weak ontological emergence, for making sense of there being entities that are both physically acceptable (as per Physicalism) and ontologically irreducible to any physical entities (as per Non-reduction). This much vindicates the bare possibility of the NRPist’s position. Moreover, the irreducibility at issue in Weak ontological emergence has various advantages: it is compatible with theoretical deducibility; it does not invoke an unsatisfactory causal overdetermination; it does not require multiple realizability for its implementation; and (thanks to the distinction between eliminations and mere reductions and restrictions in DOF) it provides an intuitively correct basis for sorting physically acceptable entities as ontologically reducible, or not. So far, so good, then, for the viability of an NRP based, at least in part, in Weak ontological emergence.

Where does this leave NRP? A remaining question one might have at this point concerns the ontological status of the mental goings-on whose treatment poses the greatest challenge to the physicalist. At least some part of the attraction of NRP is the evident desirability of preserving mental phenomena as irreducible, both for purposes of confirming our self-conception as to some degree ontologically autonomous from purely physical goings-on, and (in combination with Physicalism) providing a means of resolving the problem of mental causation in such a way as to preserve the causal relevance of the mental. Can attention to DOF provide illumination on this crucial score, hence establish that NRP is a live position, for the cases that really matter?

The answer is: I’m not sure. It is not obvious that mental phenomena involve an elimination in DOF; but given our present rudimentary level of theoretical insight, it is also not obvious that they don’t. This much I am sure of, however: even if mental
entities do not satisfy Weak ontological emergence, attention to DOF advances the physicalism debates, since we thereby not only establish NRP’s in-principle viability, but also narrow down the question of NRP’s truth to those cases of entities not satisfying Weak ontological emergence.

This is just to say that more work needs to be done in establishing whether the NRPist’s thesis extends to all broadly scientific entities—that is, in establishing whether NRP is true. But if I’m right, the NRPist is off to an excellent start.

References


