Lonergan's Oddly Strong Theory of Emergence

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Abstract

Jessica Wilson (2021) offers three characterizations of strong emergence: (1) heuristically, when higher-level features cannot in-principle be deduced from lower-level features, (2) the rejection of Physical Causal Closure in the emergence hexalemma, and (3) when a higher-level feature depends on lower-level features but has a novel power. I explicate Bernard Lonergan (1992 [1957])'s account of emergence to argue that these three characterizations come apart. Lonergan's account is only weak emergence according to (1), and affirms Physical Causal Closure by denying adjunct premises rather than any of the assumptions of the emergence hexalemma, yet counts as strong emergence according to (3).

Wilson's Account of Emergence

Jessica Wilson (2021, p. 1) begins from a heuristic account of emergence as "the coupling of *cotemporal material dependence* with *ontological and causal autonomy*." She follows recent custom in distinguishing between *weak* and *strong* versions of emergence. Other authors like David Chalmers (2008) have generally characterized this distinction in epistemic terms, as one between higher-domain truths which are "unexpected" but "nevertheless deducible in principle" and those that are "not deducible even in principle from truths in the low-level domain." Wilson (2021, p. 153) wishes to move from this epistemic characterization for two reasons: first because the inter-level metaphysical relationship is the real issue (with epistemic concerns playing only a heuristic role), and second because in-principle failures of deducibility are only necessary and not sufficient to make emergence physically unacceptable (and hence *strong*). Influenced by contemporary neo-Aristotelian powers-based ontologies, Wilson (2021, pp. 51, 53) defines strong and weak emergence in those metaphysical terms:

> **Strong Emergence**: Token [higher-level, special-science] feature[1] *S* has, on a given occasion, at least one token power not identical with any token power of the token [lower-level, physical] feature *P* upon which *S* cotemporally materially depends, on that occasion.
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> **Weak Emergence**: Token [higher-level, special-science] feature *S* has, on a given occasion, a non-empty proper subset of the token powers of the token [lower-level, physical] feature *P* on which *S* cotemporally materially depends, on that occasion.

[1] "Following Kim and standard practice, I assume that entities (objects, systems, or other particulars) are efficacious in virtue of having efficacious features (states, properties, behaviors, or other ways for entities to be). For example, the effects that a billiard ball causes (can cause) are a matter of what features it has—its mass, shape, velocity, and so on. Correspondingly, in what follows talk of entities' causing effects is suppressed in favor of talk of their features' causing effects. The assumption that the efficacy of entities lies in their having efficacious features is conveniently consonant with the usual assumption that the emergence of entities is ultimately a matter of the emergence of certain features" (Wilson, 2021, p. 40).

Wilson (2021, pp. 16, 39ff) then makes the striking claim that these are the "two and only two schemas for—schematic characterizations of—metaphysical emergence." These two schemas should somehow capture what historical emergentists were really aiming at, and we should be dissuaded from calling other views genuine instances of metaphysical emergence. The aim of this paper is to show that by Wilson's own criteria Bernard Lonergan (1992)'s account escapes this dilemma.

Wilson (2021, p. 41) supports her claim that there are only two kinds of metaphysical emergence by offering a hexalemma: a set of six premises which jointly result in a contradiction, but any five of which offer a jointly coherent view attractive to some philosophers. The six assumptions of the hexalemma are:

1. **Dependence**. Special-science features cotemporally materially depend on lower-level physical features (henceforth, 'base features') in such a way that, at a minimum, the occurrence of a given special-science feature on a given occasion minimally nomologically supervenes[2] on base features on that occasion.
2. **Reality**. Both special-science features and their base features are real.
3. **Efficacy**. Special-science features are causally efficacious.
4. **Distinctness**. Special-science features are distinct from their base features.
5. **Physical Causal Closure**. Every lower-level physical effect has a sufficient purely lower-level physical cause.
6. **Non-overdetermination**. With the exception of cases of the double-rockthrow variety, effects are not causally overdetermined by distinct individually sufficient cotemporal causes.

Then Wilson presents an argument, adapted from those made by Jaegwon Kim, that the six premises are jointly incompatible. The argument takes two forms, depending on whether the efficacy of the special-science feature (hereinafter *S*) is supposed to be found in its causation of another special-science feature (hereinafter *S**) or a physical feature (hereinafter *P**). I will focus on the version where *S*'s efficacy is found in causing *S** since, as discussed later, Lonergan does not envisage so-called "downward causation" whereby special-science features cause physical features. This version of Wilson (2021, p. 42)'s hexalemma argument goes as follows:

E: *S* causes *S** (by *Reality* and *Efficacy*)

M: *S** is cotemporally materially dependent on *P** (by *Reality* and *Dependence*)

P: *P* causes *P** (by *Reality* and *Physical Causal Closure*)

C: *P* causes *S** (by M, P, plausible assumption about causation)

D: $P \neq S$ (by *Distinctness)*

O: *S** is causally over-determined in a non-double-rockthrow way (by E, C, D, M)

The argument (pictured in Figure 1) is obviously informal, but it has been broadly accepted in the literature. Its conclusion, O, denies *Non-overdetermination* on the basis of the other five assumptions, so

[2] "In worlds with relevantly similar laws of nature, any given token of the supervenient (e.g., special-scientific) type requires, for its occurrence, a token of some base (e.g., physical) type; and in such worlds, if any token of that base type occurs, then a token of the supervening type will occur" (Wilson, 2021, p. 41n5).

if *Non-overdetermination* is introduced as a premise, any of the other five assumptions can be rejected by *reductio ad absurdum*.

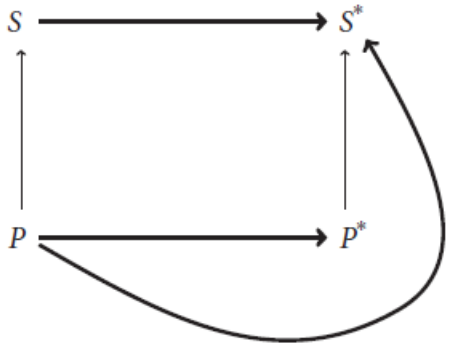

Figure 1: Wilson's Hexalemma Argument (from Wilson 2021)

Wilson (2021, pp. 43–44) then associates the denial of each assumption of the hexalemma with a popular view:

1. **Substance dualism** or Pan/proto-psychism. Deny *Dependence*: avoid overdetermination by denying that *S* and *S** cotemporally materially depend on base features *P* and *P**, respectively.
2. **Eliminativism**. Deny *Realism*: avoid overdetermination by denying that *S* and *S** are real.
3. **Epiphenomenalism**. Deny *Efficacy*: avoid overdetermination by denying that *S* is efficacious.
4. **Reductive physicalism**. Deny *Distinctness*: avoid overdetermination by denying that *S* is distinct from *P*.
5. **Strong emergentism**. Deny *Physical Causal Closure*: avoid overdetermination by denying that every lower-level physical effect has a sufficient purely lower-level physical cause.
6. **Weak emergentism/Nonreductive physicalism**. Deny *Non-overdetermination*: allow that effects caused by *S* are overdetermined by *P*, but maintain that the overdetermination here is of an unproblematic *non*-double-rock-throw variety

While Wilson takes each of these as a coherent position, and argues that different cases from the literature call for different choices, depending on the empirical facts, each of the six assumptions is independently attractive, and so each resolution to the hexalemma involves some pain. Since emergentists would not want to be associated with views 1-4, and much of the book is devoted to arguing that Wilson's characterization of weak emergence is the only metaphysically adequate version of nonreductive physicalism, the hexalemma supports Wilson's claim that there are only two varieties of emergence.

Before we proceed further to examine Lonergan's theory of emergence and its relation to Wilson's hexalemma, I would like to more carefully examine two of Wilson's premises whose precise reading will bear on the solution. The first of these is *Physical Causal Closure*, which Wilson (2021, p. 41) defines as "Every lower-level physical effect has a sufficient purely lower-level physical cause." By this strict definition, Lonergan (1992, pp. 125, 158, 280) rejects *Physical Causal Closure*, since he denies determinism and agrees that determinism blocks emergence. There are good reasons to reject this strict formulation of *Physical Causal Closure* in terms of a sufficient (and hence deterministic) cause which

have nothing to do with emergence, however. Important interpretations of quantum mechanics posit fundamental indeterministic laws, and determinism may not necessarily hold in general relativity, either (Smeenk & Wüthrich, 2021). Objective collapse interpretations of quantum mechanics, for instance, are committed to denying the sufficiency of prior physical states for determining future ones (Ghirardi et al., 1986), even though many accounts of their metaphysics are thoroughly reductionist (Allori et al., 2014).

Thankfully for Wilson's basic analysis of the emergentist hexalemma, she has offered other formulations in recent work which are not committed to the omnipresence of sufficient physical causes. In a paper intended to summarize her decades of work on the subject, Wilson (2015) characterized *Physical Causal Closure* as "Every lower-level physically acceptable effect has a purely lower-level physically acceptable cause." This version respects the possibility of fundamental indeterministic physical laws while still justifying premise **P** of the emergence hexalemma argument. Therefore, going forward, I will assume this earlier version of *Physical Causal Closure* in analyzing Lonergan's theory of emergence.

The second assumption of Wilson's hexalemma which warrants greater scrutiny is *Dependence*. Wilson (2015) defined *Dependence* as when "special-science features (at least nomologically) require and are (at least nomologically) necessitated by base features." This formulation successfully precludes dualism by tying together the physical and special-science features, but it is an odd definition of dependence because it is a fundamentally symmetrical account at odds with the asymmetrical connotation of "dependence." Nonetheless Wilson needs the symmetrical relation for her account, as the requirement of *S** for *P** is invoked in premise **M** and the sufficiency of *P** for *S** is invoked implicitly in premise **C**. The later version of the account packs this symmetry into a non-standard definition of supervenience (ordinarily an asymmetric relation of requirement): "In worlds with relevantly similar laws of nature, any given token of the supervenient (e.g., special-scientific) type requires, for its occurrence, a token of some base (e.g., physical) type; and in such worlds, if any token of that base type occurs, then a token of the supervening type will occur" (Wilson, 2021, p. 41n5).[3]

The asymmetric connotation of "dependence" is then taken up by the further notion of "cotemporal material dependence." While Wilson does not analyze the notion of "cotemporal material dependence" itself, she does tell us that "For a feature *S* to cotemporally materially depend on a feature *P* is for the entity bearing *S* to cotemporally materially depend on the entity bearing *P*" (Wilson, 2021, p. 11). Where these two entities are distinct, this might provide the desired asymmetric connotations, but Wilson (2021, p. 11n10) also allows that, trivially, "an entity can cotemporally materially depend on itself," in order to extend her account to putative cases of feature-only emergence, without emergent entities. Nothing in Wilson's account, therefore, guarantees that *Dependence* is an asymmetric relation of special-science to physical entities. Any asymmetry in the relationship depends on additional un-analyzed assumptions about grounding, which will come to the fore when we examine Lonergan's account of emergence.

Lonergan's Account of Emergence

Lonergan's account of emergence is characteristically compact, but understanding it requires unpacking Lonergan's also-characteristically dense use of bespoke terminology. The first term of art Lonergan (1992, p. 103) uses is *conjugates*, which in their pure/explanatory guise relevant to scientific theorizing are "correlatives defined implicitly by empirically established correlations, functions, laws, theories,

[3] For more standard definitions, see Kim (1984).

systems." The example Lonergan gives is Newtonian mass and force, which are defined not by anything directly sensible but by their role in Newton's equations of motion, e.g. for a two-body gravitational system:

$F_{12} = m_1a_1$ and $F_{21} = m_2a_2$ (Newton's second law)

$F_{12} = F_{21}$ (Newton's third law)

$F_{12} = Gm_1m_2/r^2$ (Newton's law of gravitation)

$a_1 + a_2 = G(m_1 + m_2)/r^2$ (rearrangement)

$d^2r/dt^2 = G(m_1 + m_2)/r^2$, $dr/dt(t_0) = v_1(t_0) + v_2(t_0)$, $r(t_0) = d$ (definition of acceleration)

Thus, while Newtonian mechanics requires that distance and time be established by sensible measurement, mass is defined implicitly as whatever plays the correct role in the equations. Since the gravitational constant G can be calculated by a flat pendulum without recourse to its mass (Xue et al., 2020), with distance and time measurements the masses can be calculated. Of course, this mathematical model abstracts from concrete reality: there are no pure point masses with exact momenta and locations, there are no purely gravitational systems, and there are no purely two-body systems.[4] Verifying the equations of motion in a laboratory context requires treating small values as zero, ignoring measurement variation, etc., in a process Lonergan (1992, p. 270) calls "a consideration of data, not in the totality of their concrete aspects, but only from some abstractive viewpoint" such that "To employ an explanatory conjugate is to turn attention away from all directly perceptible aspects and direct it to a nonimaginable term that can be reached only through a series of correlations of correlations of correlations." Mass is a correlation of distances at times, and those distances and times are found by correlating many laboratory experiments, which themselves correlate particular motions. Attempts to imagine mass inevitably conflate it with weight.

By contrast with abstractive *conjugates*, Lonergan (1992, p. 271) introduces another technical term, *things*, which are "grounded in an insight that grasps, not relations between data, but a unity, identity, whole in data; and this unity is grasped, not by considering data from any abstractive viewpoint, but by taking them in their concrete individuality and in the totality of their aspects." Fido is not an abstraction defined by some set of correlations, but rather a concrete individual motivated by food both to obey and to disobey. Fido has mass, however, and is subject to gravity when trying to catch a frisbee. Mass, taken abstractly, is an element in a mathematical model, but as a particular m_1 or m_2 it must be the mass of some*thing* like Fido. "Things possess properties and are subject to laws," says Lonergan (1992, p. 271), "For the very data that, taken concretely, are understood as pertaining to a single thing may also be taken abstractly and so may lead to a grasp of…explanatory conjugates." Fido's moving mass could, in principle, be one of the correlations used to calculate the gravitational constant.

The final piece of necessary technical terminology is the *scheme* of recurrence wherein "the diverging series of positive conditions for an event might coil around in a circle" such that "a series of events A, B, C,…would be so related that the fulfilment of the conditions for each would be the occurrence of the others" and schematized as "the series of conditionals: If A occurs, B will occur; if B occurs, C will occur;

[4] Leaving aside, of course, that there are no Newtonian systems.

if C occurs,…A will recur" (Lonergan, 1992, p. 141). If a dog is born, a dog will eat; if a dog eats, a dog will find a mate; if a dog finds a mate, a dog is born.

With this technical terminology of *conjugates*, *things*, and *schemes* in hand, Lonergan explicates his theory of emergence in two brief, dense passages which I will reproduce nearly in full. The first expresses Lonergan (1992, p. 280)'s commitments to *Reality*, *Efficacy*, *Distinctness*, *Physical Causal Closure*, and *Non-overdetermination*:

> Consider a genus of things T_i with explanatory conjugates C_i, and a second genus of things T_j, with explanatory conjugates C_i and C_j, such that all conjugates of the type C_i are defined by their relations to one another, and similarly, all conjugates of the type C_j are defined by their relations to one another. Then, since C_i and C_j differ, there will be two different systems of terms and relations; as the basic terms and relations differ, all logically derived terms and relations will differ, so that by logical operations alone there is no transition from one system to the other.

Here Lonergan, unlike Wilson, carefully distinguishes between entities (*things*), and features (*conjugates*), but commits himself to C_i's parallel to Wilson's physical features *P* and *P** and C_j's parallel to Wilson's special-science features *S* and *S**. Conjugates are only explanatory when they arise implicitly from a verified system of equations, and systems of equations are verified by their correlations during experimental interventions, so Lonergan is committed to *Reality* and *Efficacy. Distinctness* is assured by the lack of overlap between the two sets of terms and relations so that there can be no identity condition (a logical operation) between them. Since explanatory conjugates are defined fully implicitly, their values can only be altered by a change in value somewhere else within their defining system of equations, preserving *Physical Causal Closure* (e.g., the force term in Newton's equations above can only be altered by changing the mass or the distance, otherwise its definition is not fully implicit in those equations). The same principle also preserves *Non-overdetermination*.

Lonergan suggests that we take subatomic particles and molecules as our example genera. Then the T_i's will be the seventeen fundamental particles of the Standard Model, and the C_i's will be the mass-energy and other quantum numbers which govern their interactions according to the Lagrangian of the Standard Model. The T_j's will be molecules of the elements of the periodic table, and the C_j's will be atomic number and periodic group which govern the stoichiometric combinations of the elements, and were implicitly derived from chemical interactions by Cannizarro's Method.[5] The T_j's also possess C_i's since molecules too have mass, spin, and electric charge.

So far, though, all we have are distinct genera, without emergence. We can order the layers by the persistence of the C_i's in the T_j's and the absence of C_j's in the T_i's (fundamental particles lack atomic numbers and periodic groups), but the layers lack any explicit relationship. Lonergan (1992, p. 287) introduces his theory of emergence proper in another compact sentence worth quoting in full:

> The key notion in the explanatory species is that any lower species of things T_i, with their conjugates C_i and their schemes S_i admit a series of coincidental aggregates of events, say E_{ijm},

[5] Atomic number was recognized over atomic weight as the key characteristic of elements and implicitly defined before subatomic particles were discovered or any relation to protons noted (Cannizzaro, 1858, 1911). For analysis of the implicit nature of this definition, see Weisberg (2007) and Wray (2018, 2022).

> E_{ijn}, E_{ijo},…which stand in correspondence with a series of conjugates C_{jm}, C_{jn}, C_{jo},…of a higher genus of things T_j.

The schemes S_i can be understood as Feynman diagrams in which the same particles enter and exit with the same momenta. The events E_{ijm}, E_{ijn}, E_{ijo},… are then the various kinds of interactions which can occur within those Feynman diagrams as allowed by the Standard Model. A set of trillions of these events involving the kind of strong interactions (quark dynamical terms) holding nuclei together and electrodynamic interactions (lepton dynamical terms) holding nuclei together into molecules, in a massively complex Feynman diagram beyond any plausible calculation,[6] would correspond to the chemical conjugates summarized as $2H^0_2 + O^0_2 \rightarrow 2H^{I}_2O^{-II}$.[7] At the physical level, the interactions are stochastic, and the whole set of interactions admits no simple explanation. The aggregate of events is merely coincidental—what happened to result from certain initial conditions. At the chemical level, however, the process is anything but coincidental: it is an energetically favorable redox reaction with a classical stoichiometric description which involves no probabilities.

Comparative Analysis of Wilson and Lonergan

So far, Lonergan's account may seem puzzling in Wilson's terms. It seems like the epistemic heuristic for weak emergence, since the chemical phenomena are deducible in principle from the physical ones (the chemical conjugates correspond with the physical events, indeed they supervene upon them) but they are not so deducible in practice (the Feynman diagrams are unfathomably complex, and elude simple summary). Yet on Wilson's preferred metaphysical account, Lonergan's view seems like strong emergence since the higher conjugates have new (chemical) powers. The mystery is resolved by adverting to Lonergan's view of the dependence relation between the genera. The question for Lonergan is whether the T_j's possession of C_i's—"the laws of the lower science can be verified in things pertaining to a higher genus"—means that there are T_i's in the T_j's (1992, p. 283). After all, "If the laws of the electron are observed in the atom, it would seem that electrons exist, not only in a free state, but also within atoms" (Lonergan, 1992, p. 283). In Wilson's terms, if the entities bearing the physical features and the entities bearing the special-science features are both real and distinct, and the latter supervenes on the former, then *Physical Causal Closure* justifies premise **C**, framing Lonergan's account as a form of weak emergence which violates *Non-overdetermination*. Lonergan (1992, p. 283)'s definition of *things* precludes this outcome, however:

> [A] thing is an intelligible unity grasped in some totality of data. It follows that if any datum pertains to a thing, every aspect of the datum pertains to that thing. Hence, no datum can pertain to two or more things, for if in all its aspects it pertains to one thing, there is no respect in which it can pertain to any other.

[6] "Then the terms of the series E_{ijx} stand for a sequence of aggregates of subatomic events, where each aggregate is merely coincidental from the viewpoint of subatomic laws and schemes. Such coincidental aggregates can be represented by symbolic images, and in such images there are clues leading to insights that pertain to the higher viewpoint of chemistry" (Lonergan, 1992, p. 287).

[7] "The series of relations constitutive of the periodic table; these relations define implicitly the conjugates Cjx; such conjugates both differentiate the chemical elements which are the things Tj, and stand as the higher system that makes systematic the coincidental aggregates E_{ijx}" (Lonergan, 1992, p. 288).

There can be no T_i's in the T_j's, no physical entities bearing physical features *P* and *P**. How, then, are we to account for the existence of the events which correlate with the higher conjugates, underpinning emergence? Lonergan (1992, p. 284) grants that the events are interactions of the conjugates, so the lower conjugates (the C_i's) must remain, but denies that the "things defined solely by the lower conjugates also survive." Instead, all of the C_i's must be borne by the T_j's. Lonergan (1992, p. 284) justifies this remarkable view[8] by contrasting his definition of *things*, which involve totalities of data, with his definition of *conjugates*, where "abstractive procedures are normal; one considers events under some aspects and disregards other aspects of the same events."

We know that conjugates can be of use even outside of the things which they define. For example, Newton's laws canvassed earlier make no mention of charge, or charged things (only masses, hence by inference massive things), yet we can use our knowledge of masses and Newton's second law, in combination with Coulomb's law, to arrive at the magnitude of charges, and hence at the existence of charged things. More directly, charge is defined by the role it plays in the Lagrangian of the Standard Model, but that does not preclude molecules from being charged, as in the formula $2H^{I}{}_2O^{-II}$ above, indicating that H_2O is a polar molecule. Things can bear conjugates (entities can bear features) quite apart from their definitions, so long as their definitions do not preclude such conjugates, since the definitions of conjugates do not restrict what instantiations can play their roles.

This leaves Lonergan's account in just the place allowed by Wilson, where *S* materially depends on *P* (or equivalently, *S** depends on *P**) in the sense that *S* and *P* are borne by the same entity, T_{jm}, which trivially materially depends on itself, satisfying *Dependence*. The dependence relation between *P* and *S* (the C_i's and the C_j's) looks symmetrical. Indeed, given that the T_j's bear both the C_i's and the C_j's, the physical and special-science features, why should the T_j's count as emergent special-science entities rather than physical entities in the first place? Lonergan's answer is that there is a special, essentialist relationship between the T_j's and the C_j's: the T_j's are defined by their C_j's, not by their C_i's.

Hydrogen without atomic number one is not hydrogen; oxygen without atomic number eight is not oxygen. Hydrogen and oxygen have mass, but their masses vary, and the atomic masses given in the periodic table are merely coincidental average values on earth. ^{2}H and ^{3}H are still hydrogen even though their masses are double and triple that of the most common isotope. Not only ^{16}O, ^{17}O, and ^{18}O but even ^{11}O and ^{26}O are still oxygen. Molecules are ordinarily neutrally charged, but H_2O ionized to $[H_2O]^{1+}$ does not lose its chemical identity. In some important sense, then, the grounding relationship flows downward from the C_j's to the C_i's, *S* to *P*. The special-science feature of atomic number defines the entity which bears both that special science feature and the physical features. The particular token feature *P* could not exist without the particular token feature *S*, while *S* only requires some suitable *P*.

The import of Lonergan's addendum to Wilson's account of *Dependence* is that the auxiliary assumption required for premise **C** does not hold. *P* does cause *P** (premise **P**, per *Physical Causal Closure*), and *S** does materially depend on *P** (premise **M**, per *Dependence*, in the trivial way just discussed), but *P* does not plausibly cause *S**. *P*'s relationship to *P** is only probabilistic, and hence *P*'s relationship to *S** is only coincidental, while *S* offers a strong non-stochastic explanation of *S**. *S* offers a better explanation of *S** than *P* does, and so is more fittingly called the cause of *S**. Lonergan's view thus manages to count as strong emergence on Wilson's preferred metaphysical definition by introducing novel causal powers (the

[8] A view Lonergan shares with other Thomists, e.g., Patrick Toner (2008).

C_j's) without denying *Physical Causal Closure* by instead denying the adjunct assumption needed for premise **C** of Wilson's hexalemma argument in a principled way.

Nor does *S* threaten to become an over-determining cause of *P** on Lonergan's account. *P** may trivially materially depend on *S**, and even be partially grounded by it, but *P** does not supervene on *S**. Many different coincidental aggregates of events, E_{ijm}, E_{ijn}, E_{ijo},... which make up *P** are compatible with the series of conjugates C_{jm}, C_{jn}, C_{jo},... which make up *S**. H_2O can be $^1H_2{}^8O$ or $^1H_2{}^9O$, and that it resulted from $2H_2 + O_2$ does not settle which. Only a detailed analysis of the initial physical feature *P* can do that, meaning that *P* is the only plausible cause of *P** and affirming *Non-overdetermination*. Lonergan's account avoids Wilson's hexalemma.

Conclusions

Bernard Lonergan's account of emergence represents a genuine third alternative to Jessica Wilson's characterizations of weak and strong emergence. It is genuinely metaphysical, since it involves real ontological changes with distinct, real, efficacious features and entities coming into being. It is like Wilson's weak emergence because its upper-level features are in-principle deducible from its lower-level ones, but unlike weak emergence because there is no causal overdetermination. It is like Wilson's strong emergence because its upper-level features have novel causal powers, but unlike strong emergence because it invokes no downward causation. The primary cost of the account is that Lonergan decouples the tight relationship between entities and features assumed by Wilson and most other positions in the literature: lower-level features frequently exist without lower-level entities to bear them. Nonetheless it is worth investigating further since emergence is attractive to many and both overdetermination and downward causation are themselves serious costs to bear.

References

Allori, V., Goldstein, S., Tumulka, R., & Zanghì, N. (2014). Predictions and Primitive Ontology in Quantum Foundations: A Study of Examples. *The British Journal for the Philosophy of Science*, *65*(2), 323–352. https://doi.org/10.1093/bjps/axs048

Cannizzaro, S. (1858). Sunto di un corso di filosofia chimica. *Il Nuovo Cimento (1855-1868)*, *7*(1), 321–368. https://doi.org/10.1007/BF02827711

Cannizzaro, S. (1911). *Sketch of a Course of Chemical Philosophy*. University of Chicago Press.

Chalmers, D. J. (2008). Strong and Weak Emergence. In P. Clayton & P. Davies (Eds.), *The Re-Emergence of Emergence: The Emergentist Hypothesis from Science to Religion* (pp. 244-). Oxford Univ. Press.

Ghirardi, G. C., Rimini, A., & Weber, T. (1986). Unified dynamics for microscopic and macroscopic systems. *Physical Review D*, *34*(2), 470–491. https://doi.org/10.1103/PhysRevD.34.470

Kim, J. (1984). Concepts of Supervenience. *Philosophy and Phenomenological Research*, *45*(2), 153. https://doi.org/10.2307/2107423

Lonergan, B. (1992). *Insight: A Study of Human Understanding* (F. E. Crowe & R. M. Doran, Eds.; 5th ed.). University of Toronto Press.

Smeenk, C., & Wüthrich, C. (2021). Determinism and General Relativity. *Philosophy of Science*, *88*(4), 638–664. https://doi.org/10.1086/713904

Toner, P. (2008). Emergent substance. *Philosophical Studies*, *141*(3), 281–297. https://doi.org/10.1007/s11098-007-9160-6

Weisberg, M. (2007). Who Is a Modeler? *The British Journal for the Philosophy of Science*, *58*(2), 207–233. https://doi.org/10.1093/bjps/axm011

Wilson, J. M. (2015). Metaphysical Emergence: Weak and Strong. In T. Bigaj & C. Wüthrich (Eds.), *Metaphysics in Contemporary Physics* (pp. 345–402). Brill.

Wilson, J. M. (2021). *Metaphysical Emergence*. Oxford University Press. https://doi.org/10.1093/oso/9780198823742.001.0001

Wray, K. B. (2018). The atomic number revolution in chemistry: A Kuhnian analysis. *Foundations of Chemistry*, *20*(3), 209–217. https://doi.org/10.1007/s10698-017-9303-6

Wray, K. B. (2022). What happened when chemists came to classify elements by their atomic number? *Foundations of Chemistry*, *24*(2), 161–170. https://doi.org/10.1007/s10698-022-09423-0

Xue, C., Liu, J.-P., Li, Q., Wu, J.-F., Yang, S.-Q., Liu, Q., Shao, C.-G., Tu, L.-C., Hu, Z.-K., & Luo, J. (2020). Precision measurement of the Newtonian gravitational constant. *National Science Review*, *7*(12), 1803–1817. https://doi.org/10.1093/nsr/nwaa165