Scientia*et*Fides 13(2)/2025 ISSN 2300-7648 (print) / ISSN 2353-5636 (online)

Received: December 31, 2024. Accepted: June 14, 2025 DOI: http://dx.doi.org/10.12775/SetF.2025.019

Quantum Action and Substance Causation

JANICE CHIK BREIDENBACH
Ave Maria University
janice.breidenbach@avemaria.edu
ORCID: 0000-0001-6463-2355

DANIEL SADASIVAN*
Ave Maria University
daniel.sadasivan@avemaria.edu
ORCID: 0000-0003-1160-5331

Abstract. Aristotelian-Thomistic metaphysics defends a hylomorphic account of substance causation. Recent arguments have developed approaches informed by quantum mechanics (Koons 2021 and 2022, Simpson 2021 and 2023, Pruss 2018). While these arguments have responded to Jaegwon Kim's critiques concerning overdetermination and causal closure, the ontological status of substantial form, especially as it applies to the category of "thermal substances," remains an open question. In particular, do the forms of thermal substances (1) qualify as natural kinds, meeting a moderate requirement for naturalistic explanation, and (2) do they actualize the kinds of causal powers needed for substance causation in a way that avoids the event causalist's critique of explanatory vacuity? This paper defends substance causation on both counts, by relying on a robust reading of Aquinas's original account of substance causation and its distinction between corporeal and virtual contact. Far from problematizing these recent accounts, a robust Thomistic account in fact vindicates recent contemporary hylomorphic approaches, and even resolves some of the gaps that remain in a sound Aristotelian-Thomistic response to standard critiques concerning substance causation's naturalistic status and explanatory power.

* The authors would like to thank William Simpson, three anonymous referees for detailed and valuable feedback, and participants at the 2025 Symposium Thomisticum in Prague as well as the 2025 American Maritain Association Conference, at which drafts of this paper were presented.

Keywords: naturalism, explanation, powers, hylomorphism, Aquinas, Aristotle, physics, wave function

Contribution. This paper is a joint effort of both JCB and DS, who contributed their expertise and writing from diverse academic fields and research specialties: JCB is a philosopher who publishes in philosophy of causation, biology, and agency, while DS is a physicist whose publications address relativistic, quantum models for particle interactions. The original idea for the article arose from joint discussions concerning the metaphysics of wave function collapse and the ontological status of electrons. Certain sections covering metaphysics, the philosophy of action and substance causation relied especially on JCB's research specialty, while other sections covering quantum theories and experimentation, and Thomistic interpretations of the causation of light relied especially on DS's research specialty. Both authors contributed to the analysis and writing of this paper.

Use of AI. The authors declare no use of AI.

Conflicts of interest. The authors declare no conflicts of interest.

Introduction

This paper defends an ontology of substance causation, relying on a robust interpretation of Aquinas's metaphysics. Its argument builds on recent work done by philosophers of physics that compellingly support the claim that substance causation plays a central role in quantum phenomena. Like other approaches to substance causation, the Aristotelian-Thomistic variant insists on a causal category that cannot be explained wholly in terms of microphysical events or properties, and yet is also not metaphysically at odds with real activity at the microphysical level. Such a view is known as "hylomorphism," which carves out an ontological path between material reductionism or microphysicalism, on one hand, and dualism between microphysical and macroscopic objects, on the other. This paper argues that a robust Thomistic account of substance causation only strengthens such contemporary accounts of hylomorphism informed by quantum mechanics.

Jaegwon Kim's critique of metaphysical holism and irreducibility is by now familiar in the literature. "When we look for an explanation of an

event, we are typically in a state of puzzlement, a kind of epistemic predicament. A successful explanation will get us out of this state," argued Kim, while "too many explanations will put us right back into a similar epistemic predicament, which can be relieved only when we have an explanation of how the explanations are related to one another" (Kim 1997, 272). The idea of substance causation, he objected, was one such example of "too many explanations" leading to overdetermination.

Kim's complaint about explanatory overdetermination was originally intended to support microphysicalism and material reductionism, on which there are no higher level substances or powers whose activities or processes cannot be satisfactorily explained by event causation (and other types of non-holistic causation, like property causation). Kim's critique poses a central challenge for any account of agent causation, whose proponents argue that event causation entails the disappearance of the intentional agent from the causal story of action (Velleman, 1992, Hornsby 2011, Lavin 2012) as well as those committed to substance causation more broadly. This paper is concerned with the defense of substance causation from recent hylomorphist perspectives.

Many philosophers have attempted to answer Kim's challenge from an Aristotelian perspective (Steward 2012, Koons 2014, Simpson 2023, Pruss 2018, Breidenbach 2018 and 2025). It is therefore not our task to refute microphysicalism here. Rather, we ask whether a robust Thomistic approach to substance causation can survive what Alyssa Ney calls "the macro-object problem" from quantum mechanics: "the problem is to explain how the wave function of a system could ground facts about macroscopic objects" (Ney 2013, 25–6).[1] The central issue for a Thomistic account is the role of substantial form, which is purported to confer irreducible powers in ways that do not clearly relate to microphysical constituents. Such an account immediately faces the objection that it violates norms of naturalistic explanation standardly upheld by event causalists. Even if we assume that there are macroscopic objects – what Robert Koons calls "thermal substances" – can the Aristotelian-Thomistic ontology guarantee that the cause of collapse is a macroscopic power rather than one of

[1] Also cited by Tahko 2018, 157.

the lower level powers or properties involved in the context of quantum measurement? Kim's critique seems to persist: that the explanatory role of the substance is simply asserted over its microphysical properties or related quantum events, and yet such explanation by substance causation, at worst, overdetermines, and at best, is explanatorily vacuous.

In response to these persisting challenges, this paper defends a robust Thomistic account that (1) answers the naturalistic critique from event causalists, and (2) avoids explanatory vacuity.

Tuomas Tahko comments: "the jury is still out on quantum ontology. Of course, we do know some things. For instance, it seems undeniable that on all the major approaches, some kind of holism will be present in quantum ontology" (Tahko 2018, 161). This paper argues that a robust Thomistic causal ontology can show itself to be a viable solution – if not *the* solution – in response to the measurement and macro-object problems. Aquinas specifies a controversial "contact requirement" for all action in nature, and maintains a view of real powers possessed by lower level constituents without threatening the irreducibility of substantial form. His distinction between corporeal and virtual contact serves as the key to understanding how substances are movers in nature par excellence, whose causal explanation not only avoids overdetermination but proves necessary for the coherence of quantum action. For some, it may be tempting to discard some of Aquinas's commitments in the service of tailoring one's substance causation to suit modern circumstances. Others may hesitate to venture forth a view that fails to be sufficiently robust in its understanding of historical concepts, thereby risking an anachronistic account at best and an incoherent one at worst.[2] This paper conversely

[2] Margreta De Grazia remarks that "anachronism is an embarrassment" not because of some chronological error but when "we impose our own modern conceptions onto the workings of the past" (De Grazia 2015, 12). Do some contemporary Thomistic philosophers of science promote arguments that are guilty of such anachronism? Such accounts are, in some basic sense, unashamedly "anachronistic" in placing Aquinas's concepts in dialogue with scientific discoveries and modern concepts that were nonexistent in medieval eras, and are arguably at risk of De Grazia's critique in that they demand a reconciliation of Aquinas's philosophy of nature with contemporary interpretations of natural phenomena. However, we can recognize at least three distinct senses of "anachronism": first, that in which usage of concepts is unforeseen by a historical thinker like Aquinas, but involves reliably univocal usage; second, that in which

argues that the apparent complications raised by a robust Thomistic account can in fact coherently resolve some of the lingering issues in the Aristotelian-Thomistic response to the challenges from microphysicalism and event causation.

1. Contemporary hylomorphism and the measurement problem

1.1. The measurement problem

A quantum particle is described by a wave function which exhibits a range of probabilities for all of its possible states; it has not specific or determined position, but rather has a "superposition." Measurement of this particle collapses the wave function such that it takes on a determinate value. The act of observation or measurement itself alters the state of the subject being studied.[3] Stephen Weinberg describes the phenomenon thus:

> There is an irreducible strangeness to quantum mechanics. A particle does not have a definite position or momentum until one or the other is measured; what it does have is a wave function. The wave function evolves deterministically – knowing the wave function at one moment, one can use the Schrodinger equation to calculate the wave function at any later time. But, knowing the wave function, one cannot predict the precise result of a measurement of position or momentum – only the probabilities of the various possible results. How do these probabilities arise, if observers and their measuring apparatus are themselves described by a complicated but deterministic Schrodinger equation? (Weinberg 1998, 26).

---

conceptual usage is equivocal, and therefore unjustified and invalid; and third, analogous usage that is inspired by an historical account, but involves some conceptual development. We believe that our account is a combination of the first and third senses, as are many contemporary Aristotelian-Thomistic arguments which sometimes accept the identification of "neo-Aristotelian" or "neo-Thomistic" approaches.

3 Simpson describes it as "the problem of how quantum systems evolve from states that are spread out (that is, states which are *superpositions* with respect to some variable that scientists are interested in measuring) to states which are localised (that is, states which are *determinate* with respect to that variable)" (Simpson 2023, 38)

This phenomenon prompts what is known as "the measurement problem." The problem, according to William Simpson, "calls for an interpretation of quantum mechanics in order to make sense of a scientist's experience of a world in which macroscopic measuring devices are seen to register determinate measurement outcomes" (Simpson 2023, 38). In particular, the question is how to make sense of the macroscopic entities within this context, in light of microphysicalism and its claim that everything is constituted by microphysical constituents such as quantum particles.[4]

The measurement problem is "notorious," says Simpson: it "remains an open problem in the interpretation of quantum mechanics precisely because of the role that *macroscopic* measurements seem to play in modifying the *microscopic* behaviour of physical systems" (Simpson 36). Central to the measurement problem is a metaphysical issue of how to understand macroscopic entities. Related to this is an epistemic gap given by the limits of experimentation: "There is no agreed understanding of how the process of wave function collapse is supposed to take place" (Simpson 2023, 38). Anthony Leggett likewise frames the problem as an epistemic matter: "Basically, the quantum measurement paradox is that most interpretations of QM at the microscopic level do not allow definite outcomes to be realized, whereas at the level of our human consciousness it seems a matter of direct experience that such outcomes occur" (Leggett 2005, 871).

It seems undeniable that macro-objects are somehow constituted by microphysical parts. At the same time, if we assume that macrophysical entities involved in quantum measurement are *nothing but* their quantum constituents, then how is measurement possible at all? That is, how can something indeterminate result in determinate measurement out-

[4] Richard Feynman articulates this basic claim in his lectures on physics: "if we were to name the most powerful assumption of all, which leads one on and on in an attempt to understand life, it is that *all things are made of atoms*, and that everything that living things do can be understood in terms of the jigglings and wigglings of atoms" (Feynman 1963, 59). "The most important hypothesis in all of biology…is that *everything that animals do, atoms do*. In other words, *there is nothing that living things do that cannot be understood from the point of view that they are made of atoms acting according to the laws of physics*. This was not known from the beginning: it took some experimenting and theorizing to suggest this hypothesis, but now it is accepted, and it is the most useful theory for producing new ideas in the field of biology (Feynman 1963, 20).

comes? Robert Koons characterizes the problem as one leading to an infinite regress: "A quantum measurement consists in an interaction between a human experimenter, various experimental materials (instruments, laboratory setups, and the like), and a source of quantum particles. But macroscopic entities (like experimenters and their instruments) are themselves entirely composed of quantum particles, and so quantum dynamics should apply to them as well. This leads to an infinite regress: probabilities of probabilities of probabilities, ad infinitum" (Koons 2022, 152).

1.2. Event causation and the naturalistic critique

Assuming an ontology of event causation, there is a relatively straightforward way of resolving the measurement problem: simply posit that an event α [measurement] causes an event β [wave function collapse]. The present unknowns concerning what happens here will be untangled eventually by scientists; but there is no objection in principle to describing the phenomenon this way, and the causation seems undeniable. Causation in terms of events avoids an unnecessary dualism between macro- and micro-objects.[5]

Event causation is the cornerstone of standard accounts that go by the name of "causal theories of action" (CTA), which dubiously claim both Aristotle (Aguilar and Buckareff 2010) and Hume (Smith 1987) as among its progenitors. The target of CTA or "the standard story of action" is intentional action, or change that is produced by an intentional agent. According to CTA, there is no agent causation that does not simply reduce to a causation of events. As Donald Davidson argues: "Some causes have no agents. Among these agentless causes are the states and changes in persons which, because they are reasons as well as causes, constitute certain events free and intentional actions" (Davidson 1963/1980, 19).[6]

---

[5] The causal theory relies seminally on Davidson's view in the philosophy of action (anomalous monism), but also in Jaegwon Kim's philosophy of mind. Kim: Properties can cause other properties. Strictly speaking, this is causation "between instantiations of properties, or property instances" (Kim 2000, 209n6).

[6] Causal theorists such as John Bishop have followed Davidson closely, for instance where Bishop argues that "[A] causal theory of action (or, to name it more precisely, an

On the Aristotelian-Thomistic approach, substance causation may be treated as the genus of agent causation, since intentional agents (i.e. intelligent animals in general) *are* substances, but they do not exhaust the category of substance. Indeed, Aquinas uses the term "agent" both to describe non-living movers in nature as well as intelligent, intentional agents: he distinguishes between "natural agents" and "intellectual agents" (SCG III.3).[7] On Aquinas's view, there is a certain metaphysical continuity between agent causation and (non-sentient) substance causation. This continuity is welcomed by causal theorists who insist that event and action explanation alike should remain naturalistic. The advantage of a causal ontology of events is that it accords best with naturalism and the requirement of causal closure; it avoids Kim's objection of overdetermination. Event causal theories allow us to treat as wholly unproblematic the measurement problem. Thus, John Bishop argues:

> I see no reason why appeal to agent-causation thus understood [as event causation] should be controversial. Agent-causation*ism*, however, is another matter. For agent-causationists claim that the way we naturally think of actions in terms of the special relation of agent-causation must be the way actions are realized in the world: that is, for actions to be instantiated there need to be ontologically irreducible relations of agent-causation. Since prevailing naturalist metaphysics exclude irreducible agent-causation (and, indeed, irreducible substance-causation of any kind), agent-causationism rejects the

---

event-causal theory of action) maintains that episodes of agent-causation can properly be understood *as constituted wholly by events and states of affairs within the natural causal order*, as the prevailing natural scientific metaphysics interprets it. For a causal theory of action (CTA) makes the positive ontological claim that actions consist in behavior caused by mental states and events that constitute the agent's *having his or her reasons* for performing behavior of that very kind. A CTA thus implies that *intentional* explanations (explanations in terms of an agent's reasons for acting), though they are to be given a realist interpretation, do not involve irreducible ontological commitment to agent-causation, but only to event causation of behavior by the agent's relevant mental states and events. If a CTA is true there can be no mystery about how actions belong to the natural causal order, provided—as I will here simply assume—there is no mystery about how mental states and events may do so" (Bishop 2010, 71).

7 Aquinas explains the distinction thus: "The intellectual agent [agens per intellectum] acts for an end as determining on its end. The natural agent [agens per naturam], however, though it acts for an end…does not determine on its end, since it does not know the *ratio* of end, but is moved to the end determined for it by another" (SCG III.3).

> possibility of natural agency and so repudiates reconciliatory naturalism. But reconciliatory naturalism may be secured, and doubt about the possibility of natural agency removed, by a CTA that does not simply identify actions with their intrinsic events (under the right causal conditions), but, rather, holds that actions, which are conceptually agent-causal relations, may be wholly realized in event-causal relations of the same admissible in naturalist ontology. On this account of the matter, what ontologically realizes an action is its intrinsic event *in a causal context of the right kind* (Bishop 2010, 79).

This standard causalist demand, for substance causation to be naturalized such that it is "wholly realized" in event-causal terms, seems radically over-strong. We must reject it as unreasonable simply because it grants the event causalist everything he needs without any argument whatsoever. To assert that "naturalist metaphysics exclude[s]…irreducible substance-causation of any kind" presumes an account of naturalist metaphysics or description that is unjustifiably narrow; to insist that a naturalist metaphysics can only be in event-causal terms simply begs the question that must be investigated.

We can meet the demands of a naturalistic explanation within the limits of a meaningful substance causation – one that is irreducible to event causation. Recent work on substance causation by Helen Steward has endeavored to show that substance causation is both paradigmatic in the natural world and irreducible to other causal varieties (Steward 2012). Even if we grant continuity between substance causation and natural phenomena – whose causal relations might be explained in terms of events or properties – another standard causalist critique of substance causation remains. Davidson frames this objection in terms of substance causation's explanatory vacuity: the claim that I caused my own action explains nothing. "What distinguishes agent causation from ordinary causation is that no expansion into a tale of two events is possible, and no law lurks. By the same token, *nothing is explained*" (Davidson 2001: 53, italics mine). Worse, substance causation entails overdetermination, as Kim has argued (Kim 1989, 1993, 1998).

1.3. The macro-object problem and the persistence of overdetermination

Alyssa Ney interprets Schrödinger's thought experiment as a "macro-object problem": "the problem is to explain how the wave function of a system could ground facts about macroscopic objects" (Ney 2013, 25–6).[8] This approach seems to assume an emergentist framework for confronting the problem of macroscopic interaction with microscopic activity: a subvenient base produces and determines the higher level powers and properties that supervene on the lower. The coherence of emergentism has been challenged by Kim, particularly regarding its synchronic causation. Even if one defends a non-emergentist variety of substance causation (such as Steward's 2012 or Koon's 2022[9]), such accounts may reasonably be thought to be susceptible to the same challenge (Breidenbach 2018 and 2025). On the Aristotelian-Thomistic concept of substance causation, standard accounts of emergentism must be false, since they contradict the principle of prior actuality. Yet from the microphysicalist's perspective, if the emergentist ontology of supervening macro-objects entails overdeterminism by epiphenomenal entities, then the Aristotelian-Thomistic concept of substance as ontologically irreducible *and* non-supervening nor emergent is likewise guilty, *a fortiori*.

Some defenders of substance causation express uncertainty about their own commitments. Tahko cautions: "I am myself thoroughly fallibilist about this issue. Should science conclusively show that substance is not a feasible category, I would be prepared to give it up" (Tahko 2018, 161). Even if we were never to see conclusive empirical support for or against a metaphysical concept such as substance causation, microphysicalists will still assume that the question should be settled as an empirical matter. The jury may still be out, but it will eventually come to a decision in favor of the "best physics." Presumably a critic like Kim would not be persuaded by contemporary hylomorphic arguments so far because they

---

8 Also cited by Tahko 2018, 157.

9 Koons calls his version "escalation" precisely because, he argues, the term "emergentism" is so laden with problematic concepts.

seem to merely assert an ontology of macroscopic objects, in the face of empirical evidence that says (or ultimately will say) otherwise.

Microphysicalists and event causationists therefore are charged with a specific task: "to…[defeat] the arguments of *agent-causationists* who insist that genuine actions must involve an *ontologically irreducible* special kind of causal relation where the cause is a substance, namely, the agent" (Bishop 2010, 71). Substance and agent causationists, in response, aim to defend precisely this concept of ontologically irreducible causal relation. Recent strategies have included advancements on the metaphysical front[10], but also attempts that rely on precisely the kind of empirical support that microphysicalists have thought impossible or unlikely.

2. Contemporary Aristotelian-Thomistic solutions

In what follows, we assess recent Aristotelian-Thomistic accounts that purport to solve the measurement problem from a substance causation perspective. Such accounts, also known as "hylomorphist" theories, are notable for their engagement with quantum mechanics and interpretation of the empirical and experimental sciences through an Aristotelian-Thomistic lens. We will defend these recent accounts as satisfactorily answering both the naturalistic critique as well as the critique from sufficient explanation.

2.1. Macro-objects and quantum mechanics

It seems clear that what happens in the collapse of the wave function is something that stands in need of a causal explanation. What is the causal agent of what happens here? According to Aristotelian-Thomistic philosophers, such a happening must be attributed to a substance. Recent accounts argue that only such an ontological category can avoid the threat

[10] Much discussed in the literature is Davidson's own objection from deviant causal chains, which Davidson himself was not able to overcome. Event causation fails to refute the Aristotelian-Thomistic picture of active and passive powers "of the different natures operative in the universe, making intelligible their patterns of action and interaction" (Braine 1992, 227). Thomistic philosophers like Braine present the concept of patterns without law-like prediction.

of infinite regress of probabilities posed by the measurement problem. That is, the causal agent must be qualitatively distinct from quantum systems that are subject to quantum dynamics and laws of superposition.

It is at present impossible to determine precisely what constitutes a causal agent or "observer," given the closed features of experimentation that result in the collapsed wave phenomenon.[11] Although what constitutes an observer remains an open question for now, we can state with near certainty what an observer is *not*, and what it is not *necessarily*. For instance, we can probably say with confidence that an observer is not *necessarily* an animal or living agent, or anything with intentionality and consciousness. We can also say that an observer cannot be a single electron, or even congeries of electrons.

Koons argues for this latter claim based on experimental physics (such as the double slit experiment) interpreted in the light of "perennial philosophy" – the metaphysics of Aristotle and Aquinas. This metaphysics requires us to distinguish between actuality and potentiality, so "the electron is not a substance—it is rather a feature or an *action* of the substantial source that generates the electrons. This action has the unactualized potential of affecting both the left and right slit simultaneously. However, when actualized, the electron will always be in exactly one place at each time" (Koons 2022, 57).

The key question is whether an electron is already actualized by a substantial form or not. If it is an accident of a substance, then it lacks a substantial form (even if it has an accidental one), and is only potentially an accident until it in fact inheres in a substance. The empirical evidence by itself seems to show that electrons are *not* substances in this way, since they lack determinate values until actualized. Koons argues further that Aristotle's homonymy principle – which argues that a proper part such as a hand is "a hand in name only" when constituting the body – applies in such cases (*Meta.* VII.11, 1035b10–32). Hence, Koons argues that "in quantum mechanics, elementary particles do not qualify [as substances]. In quantum mechanics, particles lose their individual identities as a result of being incorporated into quantum systems. When we have a unified

[11] Barros and Oas 2017; Barzegar and Oriti 2024.

or entangled system, we can say that the system contains in some sense contains [sic] *two* particles, and yet there is no distinct identity associated with either particle" (Koons 2022, 90–91).

In what follows, we will assume an interpretation of quantum physics and the collapse of the wave function that has been accepted by many hylomorphists.[12] Simpson, for instance, defends Drosser and Ellis's CWC (contextual wavefunction collapse) theory[13], which posits that "the stochastic corrections that collapse the wave function depend upon the *macroscopic context* of the system. … [H]igher-level powers are implicated in *all* motion and lower-level powers are *never* sufficient to determine where matter ends up" (Simpson 2023, 40–41). Simpson interprets CWC theory as giving ontological priority to the macrophysical, construing its classical objects as substances.

In rejecting causal closure of the microphysical, CWC theory "raises metaphysical questions concerning how the microscopic world of quantum systems and the macroscopic world of their measuring devices are supposed to be related: for instance, how are properties like temperature and chemical entropy, which characterise an open quantum system's environment, supposed to 'emerge' from a microscopic base?" (Simpson 2023, 40). Simpson argues that CWC theory avoids both microphysical reductionism as well as dualism. Rejecting reductionism entails that the macroscopic asserts an independent role, and cannot simply be explained in terms of microscopic causal powers. Rejecting dualism entails that the macroscopic cannot interact with the microscopic as fundamentally distinct powers and processes; rather, we must see "the behaviour of microscopic entities" as occurring "within particular macroscopic contexts" (Simpson 2023, 41). The measurement problem and its metaphysical questions can only be resolved by reference to Aristotle and Aquinas's ontological category of irreducible substantial forms.

---

[12] Tahko thinks that "the possibility of pluralist substance ontology—does not necessarily depend on which approach to quantum mechanics is adopted. This is because there are versions of all the major approaches that may enable the type of ontology that the neo-Aristotelian seeks" (Tahko 2018, 157). Presumably he would likewise accept Drosser and Ellis's non-reductionist view, since it is incompatible with a monist account like Schaffer's, of which he is critical (Tahko 2018, 160).

[13] Drosser and Ellis 2018.

2.2. Thermal substances and substantial forms

To avoid the threat of infinite regress posed by the measurement problem, we must suppose that inanimate quantum observers are substances, which Koons calls "thermal substances." Following Aquinas, Koons argues that "a substance must have its own per se unity through time, an identity distinct from that of all other substances" (Koons 2022, 90). This "per se unity" is achieved not only in the metaphysical structure of a substance but in its causal powers qua substance; its principle is the thing's substantial form.[14] The unity of a thermal substance is achieved by its own actualizing principle, the substantial form of a thermal substance: "The chemical and thermodynamic properties of the thermal substances constitute their form; the quantum potentialities of their virtual parts, their matter" (Koons 2022, 235).

Thomistic defenders of "powerism" or a "powers ontology," such as Koons, are committed to "forms and processes. It is processes that *manifest* powers, and it is forms that *ground* them. Causal powers come in two kinds: active and passive. An active power initiates a process of change (kinesis) in some entity, and a passive power is the potentiality for undergoing such a process" (Koons 2022, 63).

> Powers appear in nature in natural clusters, and these power-clusters are the expression of the presence of Aristotelian *forms* (Inman 2018). Functionally equivalent or interchangeable forms constitute the basis of natural kinds of substances, whether essential or accidental. Without forms as the common ground of these repeatable clusters of powers, we would be left with a large number of massive brute coincidences. The substantial form of water explains why the active and passive powers associated with all instances of water are found so regularly in concert (Koons 2022, 63–64).

[14] As Koons and Simpson accurately interpret him, Aquinas defends a single substantial form, or what Simpson calls "a unitarian doctrine of substantial form" (Simpson 2022, 56). Scotus and other later medieval thinkers, however, rejected this claim, positing a multiplicity of such forms. We will not consider the dispute on this question here, as it is a sufficient task to defend even a single substantial form within a body that is a substance.

From the microphysicalist perspective, an obvious problem arises: how *could* there be macroscopic objects, given superposition? Even emergentism seems unlikely. What Aristotelian-Thomists identify as substance causation is much more plausibly explained by a form of complex networking at the molecular level: when atoms are arranged in an organized, heterogenous way, they exhibit remarkable phenomena. Richard Feynman, for instance, observes:

> If a piece of steel or a piece of salt, consisting of atoms one next to the other, can have such interesting properties; if water—which is nothing but these little blobs, mile upon mile of the same thing over the earth—can form waves and foam, and make rushing noises and strange patterns as it runs over cement; if all of this, all the life of a stream of water, can be nothing but a pile of atoms, *how much more is possible*? (Feynman 1963, 20).

Based on the microphysical arrangement alone, water exhibits extraordinarily complex powers and properties; hence, the category of macro-objects seems unnecessary. This style of objection has become common among material reductionists (Kim 1989, Sarkar 1992, Smart 1963). In response, Koons's category of thermal substance is well-placed to explain why such complex phenomena is exhibited even by simple elements like salt or water: they are themselves thermal substances, macro-objects with correspondingly macro-properties and powers. Thus, given superposition, a hylomorphic account asks: How could there *not* be substances? We would have serious problems if we tried to do without substantial forms.

Finally, thermal substances purportedly satisfy Steward's version of a naturalistic requirement: "Nature's repertoire of forms determines what kinds of entities are metaphysically fundamental" (Koons 2022, 64). There is nothing particularly extraordinary about substantial forms. If anything, they form the world as we know it. We can accept something like Schaffer's "tiling" or "partitioning" constraint, according to which the class of substances exhausts all of nature (Schaffer 2010, 41). Living substances are already accounted for within the cosmos; thermal substances make up for the rest, accounting for the inanimate (or inorganic) world.

2.3. The solution from joint exercise

According to Koons,

> The world is composed entirely of living organisms and extra-organismic thermal substances. Everything else is either a virtual or integral part of such a substance, or a remnant of a substance, or a heap or aggregate of such entities. … The virtual, quantum parts of substances lack definite location (contrary to Aristotle's expectation), enabling the possibility of long-range entanglement at that level (Koons 2022, 235).

In the measurement problem, the agent cause of the collapse of the wave function entails an infinite regress *unless* we posit that the quantum observer is a substance: something possessing the irreducibility of substantial form. Koons's explanation suggests that we should not view the causal relata as fundamentally distinct, but rather interpret collapse as an interaction of "joint exercise" between "the quantum powers of one substance and the substances making up the experimenters and their instruments," which together "precipitates an objective collapse of the quantum object's wavefunction" (Koons 2022, 160).

If we accept Koons's solution, it could be argued that Ney's "macro-object problem" – which demands that we explain precisely "how the wave function of a system *could* ground facts about macroscopic objects" – disappears entirely (Ney 2013, 25–6). There is no "macro-object problem" because, assuming the tiling constraint, there are only substances. The quantum particle and its wave function, then, is excluded from this category: it is, instead, an accident of a substance, and therefore exist only "virtually"[15] as parts of the substance.[16] How *could* a wave function

[15] The term "virtual" here should be understood in the perennial philosophical sense and not that by which modern physicists employ the phrase "virtual particles."

[16] Koons explains: "Quantum particles are temporary accidents of thermal substances: "Individual quantum particles are really just momentary accidents of substances, and so the locations of the particles do not fix the location of the substance. When not actualized by measurement, individual quantum particles are merely *powers* of interaction,typically non-localized powers. Congeries of such particles (in which the particles lack individual identities) are virtual parts of the substance" (Koons 2022, 155).

"ground" anything, as the (descriptive) accident of an accident of the substances actually at work?

Hence the solution from joint exercise presupposes the metaphysical priority of substances over their accidents. Substances have a defined location; quantum particles do not (Koons 2022, 99). It is therefore impossible for quantum particles to determine the location of the substance in which they inhere. Koons argues:

> Aristotelian pluralists deny that macroscopic entities like human experimenters and their instruments can be represented adequately by finite quantum models. Thermal substances have classical, mutually commuting properties, like chemical composition, temperature, and phase of matter, properties that never enter into quantum superpositions. When a quantum power interacts with a thermal substance and produces a change in classical properties, a "measurement" has occurred with a definite result (Koons 2022, 153).

We might build on this account by proposing that we conceive of the non-determined wave function as a potential part of the substance that collapses it. Its collapse does not merely change the particle's state as described by its wave function; it alters its very identity as now ontologically constitutive of an actual thing, where previously it was only potentially part of it.

2.4. Challenges

Does the solution from joint exercise of thermal substances successfully meet both the naturalist criterion and the explanatory sufficiency requirement posited by event causationists? In what follows, we note certain points of potential weakness in the Aristotelian-Thomistic solution from joint exercise, and propose in response a robust Thomistic account of thermal substances based on Aquinas's account of movement by contact.

The solution from joint exercise is unlikely to persuade material reductionists and event causalists; it is not our aim here to do so. Yet even Steward's more moderate naturalist might be skeptical of substantial forms as simply existing as fundamental natural kinds. The proposal also

needs to overcome the standard challenge that it doesn't actually explain anything; it simply restates the explanandum in another way.

How precisely does a quantum observer cause wave collapse? What confers the kind of causal power involved here? The claim that a substantial form is the principle of the thermal substance's power seems, arguably, explanatorily vacuous. Worse, it relies on Aristotelian-Thomistic jargon in apparently asserting irreducibility (both metaphysical and explanatory) of the thermal substance and its powers.

Another potential objection arises with respect to the homonymy principle applied to thermal substances. On this proposal, what confers unity to a thermal substance is "virtual mereology" – the parts do not actually exist. Water exists only virtually within an animal, whereas drinking water is a "substance in its own right. … This transmutation of inorganic substances into virtual parts and vice versa is an unavoidable theoretical cost of the hylomorphic picture, but it is a cost well worth paying" (Koons 2022, 83).[17] The homonymy principle is required to prevent the infinite regress that threatens in the measurement problem: Koons's solution claims that the thermal substance is not constituted by quantum particles.[18] But if the quantum particles exist only virtually within the substance, it seems unlikely that they could have any active causal powers of their own, since these powers, too, would be only virtual. Even if we reject material reductionism, the claim that there are real powers and properties exhibited at the microphysical level of things seems to defy

---

[17] Koons distinguishes between integral parts and "kinds of stuffs" e.g. water, lipids, proteins, nucleic acids (Koons 2022, 83). "The non-homonymous parts of an organism, such as its molecules, atoms, and sub-atomic particles, are only potential or virtual parts: they exist only as potential products of division or death, and as metaphysically derivative, localized aspects of the powers and potentialities of the whole substance" (Koons 2022, 87).

[18] Koons's interpretation of what happens to elemental forms within a substance might profitably engage with the Aristotelian-Thomistic distinction between types of generation and corruption: that which results from "assembling and dispersing," by which the constituent elements actually exist, and "alteration," by which the constituent elements only potentially exist (*De Caelo* III.8, 600). We assume in this paper that thermal substances are constituted through real alteration, and thus their parts are only virtual, but there may be some lingering questions about what merits this assumption for thermal substances like water versus congeries like blood or milk – these questions will need to be addressed elsewhere. Thanks to an anonymous referee for this point.

the commonsense position, if not also the view from modern physics. So is such virtual mereology truly "a cost well worth paying"?[19]

3. A robust Thomistic substance causation

In this section we defend the concept of thermal substances against the above challenges. Instead of retreating from an Aristotelian-Thomistic account commonly perceived as anachronistic or "archaic," we frame our solution around a robust interpretation of Aquinas's account in particular.

3.1. Substantial forms as movers in nature

Following Aristotle, Aquinas defends the ontological primacy of substantial forms. That is, a form is the ontological principle of what it is to be that thing, and confers on it certain powers qua substance. On Aquinas's view, there is nothing extraordinary about thermal substantial forms. He describes them as

> certain lowest forms, which are capable of no operation except such as comes within the compass of the qualities which are the dispositions of matter – for instance, heat, cold, moisture and dryness, rarity, density, gravity and levity, and similar others (like the elemental forms). Consequently, these forms are altogether material, and wholly merged in matter (SCG II.68).

---

[19] To be sure, Aquinas's account posits virtual mereology as *the explanation* for how elemental powers remain in a substance: "sunt igitur formae elementorum in corporibus mixitis non quidem actu, sed virtute," where "virtus" is commonly translated as the "power" or "excellence" of a thing (*De Mixtione Elementorum* 59). In order to avoid the problem of multiple substantial forms ("multa autem corpora impossibile est esse simul," *De Mix. El.* 14), Aquinas posits that the elemental forms whose powers are evident must be only virtual, not actual. The problem of macro-objects approaches the issue with a very different question in mind: what *is* the macro-object in the midst of microphysical particles whose presence is empirically supported, and can an ontology of macro-object be defined independently of its microphysical constituents? In the context of this question, claiming the existence of virtual parts with actual powers apparently misses the point. But which question is prior? Inquiring how the substance has its powers assumes an ontology of substance causation, wherein its evident powers are the explanandum to its virtual mereological constitution as explanans. It seems more fundamental to ask whether the concept of virtual presence makes any sense at all (thanks to an anonymous referee for this point).

Aquinas's account is neither reductionistic nor dualist: substantial forms are the principle of actuality, and therefore distinct from the potentiality of matter, even when such forms are material themselves and "wholly merged in matter." This is a thoroughly naturalistic approach to thermal substances, that simultaneously retains the framework of act and potency which grounds Aquinas's analysis of all substantial forms, from the lowest thermal existents to his speculative treatment of angelic substances. A robust account also retains the commonsense view that a thermal substance has specific powers *because* of its matter and *its* dispositions.[20] Perhaps surprisingly, Aquinas's view aligns with Feynman's view, noted above, that the properties of water are attributable to the properties of its microphysical constituents which retain actual dispositions and powers even if we treat them as parts. Yet this account does not collapse into material reductionism, because without a principle of actuality – a substantial form – there would be no *thing* to speak of. A thermal substance like water is actualized potentiality, since what previously was only potential might be compared to an uncollapsed wave function: it is not yet determined by the substantial form that acts on it.

This account does not necessarily require us to apply Aristotle's homonymy principle to thermal substances, such that its microphysical parts exist only virtually. Indeed, the language of forms "wholly merged in matter" suggest that there are no proper parts here: the electrons of a thing are to be considered its matter, not its parts.

3.2. The contact requirement

Aquinas's views on substance develop Aristotle's original claims in *Physics*, that material bodies can act only "by contact":

> Mover and moved, maker and made must be together, as proved in 7 *Physics*. Now a bodily agent cannot be present to its effect except by contact, by

[20] Some thermal substances, such as magnetic alloys, are "mixed bodies" in that their forms exhibit no "operations that cannot be accomplished through" the qualities of their matter, "nevertheless sometimes produce those effects by a higher power which they receive from the heavenly bodies, and which is consequent upon their species" (SCG II.68).

> which the extremes of contiguous things come together. Hence it is impossible for a body to act save by contact. But contact is of one thing in relation to another. And thus where there is nothing preexistent besides the agent, as happens in creation, there can be no contact. Therefore, no body can act by creating (SCG II.21).

Modern physics, however, presents a number of examples that seem to involve contactless causation: gravitational forces[21], and what Einstein called "spukhafte Fernwirkung" – the spooky action at a distance of quantum entanglement – apparently contradict Aquinas's contact requirement. Unless we are prepared to assume that such non-local physics constitutes an act of divine creation, Aquinas's contact requirement apparently lacks empirical support.

However, we can refer to a further distinction that Aquinas makes, between corporeal contact, which is quantitative, and virtual contact (contact of power), by which "the indivisible can touch the divisible" (SCG II.56). His examples are the heavenly bodies which touch elemental bodies (thermal substances) in this way, or intellectual substances united to bodies. Both present instances in which a causal agent "extends to the innermost" aspect of the things touched (SCG II.56).[22] In this context, the causation of light presents some vexing questions. Aquinas argues that light is a feature, not a corporeal body (ST I, a. 67, ad. 3–4).[23] Both he and Aristotle supposed, mistakenly, that light does not travel but illuminates instantaneously, since it acts on what is transparent and "not visible in itself" (*De An.* II.7). Although some microphysical aspects of light might qualify for virtual contact, modern physics suggests that visible illumination is more like sound, which Aristotle identifies as having a finite speed:

---

21 Such contactless causation might be possible on Newtonian interpretations of gravitational fields, but assuming relativity, Aquinas's contact requirement remains intact.

22 The original text is as follows: "Tactus autem virtutis, qui competit substantiis intellectualibus, cum sit ad intima, facit substantiam tangentem esse intra id quod tangitur, et incedentem per ipsum absque impedimento."

23 He follows Aristotle's thought on light in *De Anima* II.7 and *De Sensu et Sensibilibus* II-III, VI.

> What has the power of producing sound is what has the power of setting in movement a single mass of air which is continuous from the impinging body up to the organ of hearing. The organ of hearing is physically united with air, and because it is in air, the air inside is moved concurrently with the air outside (*De An.* II.8).

Illumination has a similar causal structure. Substance causation requires quantitative contact, but it does not exclude virtual contact. Quantum entanglement, which does not involve substances but rather microphysical parts of substances, can speculatively be explained as an instance of virtual contact. On the same tentative proposal, virtual contact likewise occurs in instantaneous wave function collapse of entangled particles.[24] Simultaneously, the precipitation of collapse by the joint exercise of thermal substances requires corporeal contact, or substance causation. Aquinas's metaphysical framework in general thus helps to explain *potentiality* in the material world, expressed in quantum mechanical terms via the microphysical constituents of reality. Even if the proposed reference to virtual contact is rejected as overly speculative, our robust Thomistic account retains the metaphysical distinction of thermal substances in this causal landscape: they are natural movers *par excellence*.

3.3. Do material forms overdetermine?

We return to Kim's original challenge that substance causation results in explanatory overdetermination. A robust Thomistic account is now equipped to show why overdetermination is no threat. Aquinas grants that microphysical parts of a substance may have causal powers. But these powers stand in instrumental relation to the powers of the substance:

> All the lower active causes must be compared to the higher causes as instrumental to primary causes. Now every substance other than God has being caused by another.... Therefore, it is impossible for it to be a cause of being otherwise than as instrumental and as acting in virtue of another. But an

[24] Bell's theorem posited that non-local wave function collapse occurs instantaneously or much faster than light.

> instrument is never employed save in order to cause something by the way of movement: for the very notion of an instrument is that it is a mover moved (SCG II.21).

The causation of microphysical matter is in the service of the substance. Even Kim admits that there is no threat of overdetermination where all causes can be explained relative to one another: here, the relationship is defined as joint collaboration. Overdetermination threatens only when causes compete, but there is no competition here.[25] One way of understanding this is in terms of CWC theory, as construed by Simpson:

> [T]he microscopic powers of the substance must be grounded in the substance as a whole at every moment. The only primary powers which matter may be said to possess, independently of any substance, are powers to be determined in different ways within different substances. Any secondary powers which a parcel of matter may possess, in virtue of being an actual, integral part of a substance, are determined by the substantial form of the substance (Simpson 2023, 42).

This account makes clear why a substantial form is a necessary ontological category even at the lowest elemental level: without it, the "disposition of matter" that Aquinas discusses in SCG II.68 could not be actually expressed. The substantial form determines these powers by providing the unifying conditions for their expression. No single water molecule exhibits wetness; the form of water, which makes these molecules part of its substance, is what determines the constituent molecules to exhibit wetness. A robust Thomistic account therefore allows for microphysical causation, while also requiring that such causal powers are subservient to the macrophysical substance, without threat of overdetermination. This is because of the way Aquinas treats the instrumentality of powers in

---

[25] Koons quotes Aquinas in *De Potentia* 3.11 ad 5 (Aquinas 1952): "An instrument is understood to be moved by a principal agent so long as it retains the power (*virtus*) impressed by the principal agent; whence the arrow is moved by the archer so long the force imparted by the archer remains.... It is necessary that the mover and moved be together at the beginning of the motion, but not for the whole motion, as is evident in projectiles" (Koons 2022, 265).

service of the higher: they cannot compete, and therefore cannot result in overdetermination.[26]

This account naturally develops a reply to the critique that substance causation is explanatorily vacuous. A robust Thomistic substance causation in fact explains everything that needs to be explained: how the same microphysical constituents can exert higher level powers as part of a micro-object. They fail to do so on their own; they can only do so as part of a substance. Perhaps most powerfully, such an account shows how explanatorily vacuous *event* causation is: without contact either corporeal or virtual, how *can* events be causes?

If microphysicalism were true, microscopic constituents by themselves, isolated from their thermal substances, could exert exactly the same causal forces as they would as part of their thermal substances. But we do not see this. Wave function collapse only occurs upon contact or proximity to a thermal substance that has substantial form. This is partly because only such a thing *could* exert causal forces like this, the acting of one substance on another thing. In the case of a robust Thomistic account merged with CWC theory, what we see is a plausible case for the claim that these uncollapsed electrons are meant to be part of the substance that acts upon it.

Conclusion

This paper has proposed a robust Thomistic account of substance causation as building on recent Aristotelian-Thomistic proposals to resolve the measurement problem. We have argued that Aquinas's account of substance causation is a metaphysical "contact sport," so to speak: substanc-

[26] A similar solution to overdetermination is outlined by Steward, via the example of a whirlpool (originally Sperry's) as a case of top-down or substance causation (2012). Breidenbach has argued (2025, 32) that the microphysical parts of the whirlpool exert fundamentally diverse but synchronic upwards causal influence on the whole thermal substance, which exerts its own causal exercise as a whole: hence, substance causation that is compatible with microphysical causal powers. These approaches align with Aquinas's view about the causal instrumentality of lower-level constituents. It is precisely because of their instrumental role that the causal powers at the lower level do not contradict or compete with those at the higher level: there is no threat of overdetermination here.

es are movers in nature, the kinds of things that *can* come into contact with another so as to move it. A substance is this kind of thing because of its substantial form. Even when its form is material, its ontological status cannot be explained away by microphysicalism, event causation, or explanations based on complex networking.

References

Aguilar, Jesús, and Buckareff, Andrei. 2010. "The Causal Theory of Action: Origins and Issues." In *Causing Human Actions*: *New Perspectives on the Causal Theory of Action*, edited by Jesús Aguilar and Andrei Buckareff, 1–26. Cambridge, MA: Massachusetts Institute of Technology Press.

Aquinas, Thomas. 1920. *Summa Theologiae*. Translated by the Fathers of the English Dominican Province. https://www.newadvent.org/summa/1.htm.

Aquinas, Thomas. 1961. *Summa Contra Gentiles*. Translated by Laurence Shapcote. https://aquinas.cc/la/en/~SCG2.

Aquinas, Thomas. 1963–1964. *De Caelo*. Translated by Fabian R. Larcher and Pierre H. Conway. https://isidore.co/aquinas/english/DeCoelo.htm.

Aquinas, Thomas. 1995. *De Mixtione Elementorum*. Translated by Peter Orlowski, ed. Joseph Kenny. https://isidore.co/aquinas/MixtioElementorum.htm.

Aristotle. 1933. *Metaphysics*. Translated by Hugh Tredennick. Loeb Classical Library 271. Cambridge, MA: Harvard University Press.

Aristotle. 1931. *On the Soul (De Anima)*. Translated by John A. Smith. Loeb Classical Library 237. Cambridge, MA: Harvard University Press.

Aristotle. 1931. *Sense and Sensibilia (De Sensu et Sensibilibus)*. Translated by William D. Ross. Loeb Classical Library 323. Cambridge, MA: Harvard University Press.

Barzegar, Ali, and Daniele Oriti. 2024. "Epistemic–Pragmatist Interpretations of Quantum Mechanics: A Comparative Assessment." *Foundations of Physics* 54 (5): 1–34.

Bishop, John. 2010. "Skepticism About Natural Agency and the Causal Theory of Action." In *Causing Human Actions*: *New Perspectives on the Causal Theory of Action*, edited by Jesús Aguilar, and Andrei Buckareff, 69–83. Cambridge, MA: Massachusetts Institute of Technology Press.

Braine, David. 1992. *The Human Person*: *Animal and Spirit*. Notre Dame: University of Notre Dame Press.

Breidenbach, Janice. 2025. “Hylomorphism and Synchronic Dependency.” *Res Philosophica* 102 (1): 19–39.

Breidenbach, Janice. 2018. “Action, Animacy, and Substance Causation.” In *Neo-Aristotelian Perspectives on Contemporary Science*, edited by William M. R. Simpson, Robert C. Koons, and Nicholas J. Teh, 235–260. New York: Routledge.

Davidson, Donald. 2001. *Essays on Actions and Events*. Oxford: Oxford University Press.

De Barros, J. Acacio and Gary Oas. 2017. “Can We Falsify the Consciousness-Causes-Collapse Hypothesis in Quantum Mechanics?” *Foundations of Physics* 47 (10): 1294–1308. DOI: https://doi.org/10.1007/s10701-017-0110-7.

De Grazia, Margreta. 2010/2015. “Anachronism.” In *Cultural Reformations: Medieval and Renaissance in Literary History*, edited by Brian Cummings, and James Simpson, 12–32. Oxford: Oxford University Press. DOI: https://doi.org/10.1093/oxfordhb/9780199212484.013.0002.

Drossel, Barbara and George Ellis. 2018. “Contextual Wavefunction Collapse: an integrated theory of quantum measurement.” New Journal of Physics 20. https://iopscience.iop.org/article/10.1088/1367-2630/aaecec

Feynman, Richard. 1963/2011. *Six Easy Pieces*. New York: Basic Books.

Hornsby, Jennifer. 2011. “Actions in Their Circumstances.” In *Essays on Anscombe’s Intention,* edited by Anton Ford, Jennifer Hornsby, and Frederick Stoutland, 105–127. Cambridge, MA: Harvard University Press.

Kim, Jaegwon. 1997. “Mechanism, Purpose, and Explanatory Exclusion.” In *The Philosophy of Action*, edited by Alfred Mele, 77–108. New York: Oxford University Press.

Kim, Jaegwon. 1998. *Mind in a Physical World*. Cambridge: MIT Press.

Kim, Jaegwon. 1989. “The Myth of Nonreductive Materialism.” In Kim 1993d. First published in *Proceedings of the American Philosophical Association* 63 (3): 31–47.

Koons, Robert. 2021. “Thermal substances: a Neo-Aristotelian ontology of the quantum world.” *Synthese* 198 (Suppl 11): 2751–2772.

Koons, Robert. 2022. *Is St. Thomas’s Aristotelian Philosophy of Nature Obsolete?* South Bend: St. Augustine’s Press.

Koons, Robert. 2014. “Staunch vs. Faint-Hearted Hylomorphism: Toward an Aristotelian Account of Composition.” *Res Philosophica* 91 (2): 151–177.

Lavin, Douglas. 2012. “Must There Be Basic Action?” *Noûs* Vol. 00, No. 0: 1–32.

Leggett, Anthony J. 2005. “The Quantum Measurement Problem.” *Science* 307 (5711): 871–872. DOI: https://doi.org/10.1126/science.1109541.

Ney, Alyssa. 2013. “Introduction.” In *The Wave Function*: *Essays on the Metaphysics of Quantum Mechanics*, edited by Alyssa Ney and David Albert, 1–50. New York: Oxford University Press.

Pruss, Alexander. 2018. “A Traveling Forms Interpretation of Quantum Mechanics.” In *Neo-Aristotelian Perspectives on Contemporary Science*, edited by William M. R. Simpson, Robert C. Koons, and Nicholas J. Teh, 105–122. New York: Routledge.

Sarkar, Sahotra. 1992. “Models of Reduction and Categories of Reductionism.” *Synthese* 91: 167–194.

Schaffer, Jonathan. 2010. “Monism: The priority of the whole.” *Philosophical Review* 119 (1): 31–76.

Simpson, William M. R. 2021. “From Quantum Physics to Classical Metaphysics.” In *Neo-Aristotelian Metaphysics and the Theology of Nature,* edited by William Simpson, Robert Koons, James Orr, 21–65. New York: Routledge.

Simpson, William M. R. 2023. *Hylomorphism*. Cambridge: Cambridge University Press.

Smart, John. 1963. “Materialism.” *Journal of Philosophy* 60: 651–662.

Smith, Michael. 1987. “The Humean Theory of Motivation.” *Mind* 96 (381): 36–61.

Steward, Helen. 2012. *A Metaphysics for Freedom*. New York: Oxford University Press.

Tahko, Tuomas. 2018. “Disentangling Nature’s Joints.” In *Neo-Aristotelian Perspectives on Contemporary Science*, edited by William M. R. Simpson, Robert C. Koons, and Nicholas J. Teh, 147–166. New York: Routledge.

Velleman, David. 1992. “What Happens When Someone Acts?” *Mind* 101 (403): 461–481.

Weinberg, Stephen. 1998. “The Great Reduction: Physics in the Twentieth Century.” In *The Oxford History of the Twentieth Century*, edited by Michael Howard, and Wm. Roger Louis. 22–34. Oxford: Oxford University Press.