A Hole Without the Whole:
Hylomorphism Against the Causal Closure of the Physical

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Abstract

Howard Robinson has criticized the contemporary revival of hylomorphism in analytic philosophy for being inconsistent with the causal closure of the physical (CCP) and, by consequence, modern science. This thesis critically evaluates Robinson's criticism.

We firstly analyze Robinson's argument and reinforce it with Jaegwon Kim's causal overdetermination argument. We then turn to CCP itself, settling its exact meaning and highlighting its problems. We argue that CCP's deferral of the meaning of "physical" to physics renders it false - if applied to present physics – or undetermined – if it refers to future physics. On top of that, a careful look at present physics shows that CCP is not actually *given* by physics, as its proponents often claim, but rather *imposed* on it.

Having considered the insufficiencies of CCP, we turn to the philosophical framework of hylomorphism, arguing that contemporary structural accounts of hylomorphism are bound fall prey to Robinson's and Kim's arguments. As such, one should embrace a more classically-inspired version of transformational hylomorphism according to which the form of substance dynamically re-identifies the material parts of an entity towards the same end as a singular causal system.

This account of form provides a cohesive distinction between substances on the one hand and mere heaps or aggregates of matter on the other. This will prove to be particularly advantageous when considering various examples from contemporary biology that defy CCP's microreductionism in showing the importance and causal relevance of biological higher-level phenomena in shaping its lower-level physical and chemical surrogates.

We conclude that CCP's picture of nature, with its monistic view of causation, is not in line with our best science. Contemporary science, from physics to biology, provides us a picture of nature where there is a constant and dynamic interplay of higher and lower-level phenomena, with both shaping each other in novel and unpredictable ways.

Aristotelian hylomorphism, with its pluralistic approach to causation, provides a much stronger metaphysical framework to ground such picture. It grounds both strong emergence and downwards causation in substantial forms and, as such, gives us the tools to understand the processual characters of substances whilst upholding their unity.

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“And of the objects which are being carried in like manner they would only see the shadows…”

— Plato, *The Republic*

"He will require to grow accustomed to the sight of the upper world… first, he will see the shadows best, next to the reflections of men and other objects in the water, and then the objects themselves; then he will gaze upon the light of the moon and the stars and the spangled heaven…"

— Plato, *The Republic*

“… the totality is not, as it were, a mere heap, but the whole is something besides the parts…”

— Aristotle, *Metaphysics*

“The ‘music of life’ plays itself”.

— Denis Noble, *The Music of Life*

1. Introduction

The causal closure of the physical (CCP, from now on) has been a topic of hot debate for now various decades in analytic philosophy. CCP was born and has been mostly deployed in debates surrounding mental causation, more often than not, to deny its possibility. The argument is rather simple: if all of causality is closed under physics, then there is nothing left for the "mental" to do.

This simple yet effective argument has been recently expanded beyond the borders of philosophy of mind. Howard Robinson, who is deeply acquainted with CCP's applications in its original context, has recently criticized the contemporary revival of hylomorphism in analytic philosophy for being inconsistent with CCP and, by consequence, modern science.

In the course of this thesis, we critically evaluate Robinson's criticism of hylomorphism. First, we carefully analyze his argument and then strengthen it with Jaegwon Kim's famous causal overdetermination argument. By combining the two arguments we will back the hylomorphist into a tough spot: in failing to encompass CCP, not only does he, according to Robinson, renounce contemporary science; he also, according to Kim, embraces an inconsistent view of causality.

The second section of the thesis considers CCP as such. We first settle the exact meaning of the principle and then argue that its deferral of the meaning of "physical" to physics is doubly problematic: for if it means *present* physics, then CCP is false; and if it means *future* physics, then it is undetermined. On top of that, we argue that a careful look at present physics shows that CCP is not actually *given* by physics, as its proponents often claim, but rather *imposed* on it. We thus conclude that CCP is problematic at various levels and not effective in an argument against hylomorphism.

Having considered the problems with CCP, we turn our attention to the philosophical framework of hylomorphism. We first argue that contemporary structural accounts of hylomorphism fall prey to Robinson and Kim's arguments by taking a very minimal account of form as mere structure. Against structural hylomorphism, we present a version of transformational hylomorphism according to which form is better understood as an irreducibly holistic principle of specificity of a thing that dynamically re-identifies the material parts of an entity towards the same end as a singular causal system.

This account of form, by being more in line with the original Aristotelian account of formal unity, provides a cohesive distinction between substances on the one hand and mere heaps or aggregates of matter on the other. This will prove to be particularly advantageous when considering various examples from contemporary biology that defy CCP's microreductionism in showing the importance and causal relevance of biological higher-level phenomena in shaping its lower-level physical and chemical surrogates.

We end the thesis by contrasting two pictures of nature, the first afforded by CCP, the second by hylomorphism. Contrary to what its proponents often argue, CCP's picture of nature, with its monistic view of causation, is not in line with our best science. We argue that contemporary science, from physics to biology, provides us a picture of nature where there is a constant and dynamic interplay of higher and lower-level phenomena, with both shaping each other in novel and unpredictable ways. Aristotelian hylomorphism, with its pluralistic approach to causation, provides a much stronger metaphysical framework to ground such picture. It grounds both strong emergence and downwards causation in substantial forms and, as such, gives us the tools to understand the processual characters of substances whilst upholding their unity.

2. Causal Closure Against Hylomorphism

2.1. Robinson's Argument

Robinson's argument is meant to mainly tackle what he calls "modern hylomorphism", that is, the structural hylomorphism as defended in its various shades by Kathrin Koslicki and William Jaworski. As such, it mainly focuses on the concept of structure.

Robinson starts by distinguishing three positions:

i) "Complex structures figure in the explanations given by the special sciences but the (physical) world is closed under physics."
ii) "Complex structures figure in the explanations of the physical sciences and the world is not closed under physics – laws are emergent [...] but the emergent laws are not teleological.
iii) "The third option is like (ii) in accepting emergence, but the emergent laws – eg of biology or psychology– are teleological" (Robinson 2014, 1-2).

According to Robinson, only iii) requires structure to have "real efficacy" as "there is no [purely] 'bottom up' explanation of the events that take place: that is, no bottom-up explanation even of where the physical parts end up located" (2). On the other two positions, one might conceive of a bottom-up explanation of structure that defies its real causal efficacy: "one might hold that it was a property of the atoms that they react to each other differently when grouped together in certain ways" (2). As such, i) ends up offering a reductionistic possibility regarding structure: even if there is indeed structure and it figures in scientific explanation, it is nothing more than the sum of its constituent parts, nothing but the spatiotemporal arrangement of the atoms that make up such structure. But iii), on the other hand, "hypostasizes" structure by taking it to be something more, something over and above, the sum of its parts. As such, Robinson argues, iii) requires the "emergence of teleology [as...] a perspective of the whole – an end in view that relates only to something with the appropriate organization" (2). The problem is that when defending 3), the reality of not only formal but by consequence final causes, one is rejecting a purely bottom-up explanation of reality and, as such, CCP.

This leaves, according to Robinson, the modern hylomorphist in a tricky position. Whereas he wants to defend a version of either ii) or iii), he also wants to be consistent with i) (CCP), and that is not possible.

Robinson thus concludes that:

> "The following argument has appeal.
>
> (1) The concept of structure is essential to all or most natural sciences.
>
> (2) If something is essential to a valid mode of explanation or understanding, then it should be conceived realistically. therefore
>
> (3) There are real structures in the world.
>
> But the following also has appeal.
>
> (4) It is sufficient for the concept of structure to be applicable that elements be appropriately related in the world, and these relations can be characterized without employing the notion of structure. This could be done by specifying the spatio-temporal location of the elements and their causal influence on each other. (11-12)

As such, structures "contribute nothing over and above the 'forces' of physics and, as entities, they are nothing above their constituents and their spatiotemporal and causal relations" (12). Thus, even if structure figures in our explanation of phenomena, it is at best a supervening phenomenon, nothing more than an aggregation of parts that is perfectly reducible to them. There is thus no reason to take structure to be real and to have causal power.

Before proceeding, it is worth assessing Robinson's argument in more detail so as to make explicit some of its hidden premises while also linking it to the broader debates regarding CCP.

Firstly, Robinson (2021) thinks that hylomorphism does not "fit nature as we now understand it" because it rests on "a kind of downward causation that explicitly rules out [CCP]" (284). That is, Robinson maintains that CCP follows from our best contemporary science and understanding of nature, and therefore, hylomorphism's inability to accommodate CCP is a good enough reason for it to be rejected.

Secondly, it is CCP that ultimately grounds 4), that structure can be explained away in terms of the "spatio-temporal location of the elements and their causal influence on each other". As such, if the hylomorphist provides good reasons to reject CCP, he can also by consequence reject Robinson's argument.

Thirdly, in the course of his argument, Robinson creates some false problems. For instance, one can hold 1), 2) and 3) without rejecting CCP. That is, one can accept that "the concept of structure is essential to all or most natural sciences", that it "should be conceived realistically" and hence "there are real structures in the world" without violating CC Weak emergentists, for example, could hold that view: structure is real as it emerges from the interaction of the constituents at the basal level, even if being perfectly reducible to them. It is therefore possible to hold CCP and the reality of emergents, even if the latter are totally dependent on their basal properties: "Weak emergence affirms the reality of entities and features posited in the special sciences, while also affirming physicalism" (O'Connor, 2020). Robinson may argue – with good reasons – that this position is unstable and has to ultimately collapse into a form of reductive physicalism, but he gives no argument to think so at this point.

So, when Robinson mentions emergence in ii) and iii), he cannot be referring to weak emergence, since he makes it clear that for both ii) and iii) the "the world is not closed under physics". In rejecting CCP, ii) and iii) thus seem to be forms of strong emergence. Again, Robinson does not use the term but it is helpful to elucidate his argument. Whereas weak emergence, as mentioned above, takes emergents to be nothing over and above their subvening basal properties, strong emergence takes emergents to possess novel causal powers not reducible to their basal properties (Wilson 2015).

Therefore, strong emergence recognizes the existence of higher-level causal powers that are irreducible, that is, not possessed by the physical bases of emergents. And these higher-level causal powers are, in turn, "directed 'downwardly' at the structures from which they emerge (as well as 'horizontally' in contributing to emergent features of the system at subsequent times)" (O'Connor 2020). This feature of strong emergence seems to be what Robinson is hinting at when he characterizes iii) as "teleological" thus requiring the emergence of "a perspective of the whole – an end in view that relates only to something with the appropriate organization". And since teleology, as Robinson argues, cannot be fully accounted for in a purely bottom-up way, in stating teleology, one is also stating a form of downwards (or top-down) causation. And that is exactly what many strong emergentists defend. In fact, it is difficult to understand strong emergence without appealing to downward causation – and vice versa. As Paoletti and Orilia (2017) see it, both concepts are "interdefinable" in that "a strongly emergent entity is one that confers/has downward causal powers, i.e., powers to be exercised with respect to the lower-level entities" and, at the same time, "a downward causal power is one that belongs to an entity of a higher, strongly emergent level and that can cause something at the lower levels" (2). A theory of strong emergence is thus also a theory of downward causation, and Aristotelian hylomorphism can be seen as one of the possible syntheses of both.

With that settled, we are in a better position to understand some nuances of Robinson's argument. To begin with, Robinson is arguing that even if one accepts a form of weak emergence and indeed posits higher-level entities in our scientific explanations, given CCP, those higher-level explanations do not map onto real causes because all real causal activity happens at the basal level. In this context, weak emergentism is purely epistemological, a mere pragmatical recognition of our intellectual and scientific limitations – we may have to appeal to higher-level structures in our explanations but that is just because we can't grasp everything that is really going on at the basal level. Consequently, we might one day be able to explain away all those higher-level features. On top of that, the reason why hylomorphism is at odds with CCP is because it depends on a theory of strong emergence – and, by consequence, of downwards causation – that argues for a "perspective of the whole" and for the existence of higher-level causal powers that are irreducible to their physical basal properties.

2.2. Call on Kim

Robinson's argument against hylomorphism can be strengthened by considering another famous argument against emergence – and, by consequence, downwards causation: Jaegwon Kim's causal overdetermination argument (or causal exclusion argument). CCP is also key in Kim's line of reasoning and, together with Robinson's, it can make an even stronger case against the hylomorphist.

Even though initially nurtured in philosophy of mind debates concerning mental causation, Kim's exclusion argument has since been applied in more general contexts. That is possible because, once stripped out of its philosophy of mind language, Kim's exclusion argument can be deployed not only against mental causation, but as a general argument against any form of emergence – and downwards causation – as it tackles all cases of "diachronic causal influence of [higher-level] emergent phenomena on lower-level phenomena" (Simpson 2023, 32).

The thrust of Robinson's argument against hylomorphism is that, given CCP, it makes no sense to postulate something such as "structure" because all relevant causal activity has to be happening at the basal level. Kim's causal exclusion argument, also relying on

CCP, strengthens Robinson's position by formally showing that emergents must be causally impotent.

Kim argues that there can be no difference in the higher-level phenomena without difference in the physical phenomena; as such, the former are fully determined by the latter. For Kim, all of causality must happen at the physical basal level. This train of thought relies, of course, on the causal closure and completeness of physics. As Kim formulates it, CCP states that "all physical states have *pure* physical causes" (Kim 1993, 280) meaning that physical events have *sufficient* physical causes. But Kim takes his defense of CCP further than Robinson – who merely states it as following from our best physics – in trying to show that, if one rejects CCP, one has to ultimately embrace a redundant view of causality.

Kim has put his own argument in a variety of forms and various authors have provided their own way of conceptualizing it. We will use Simpson's (2023) formulation of the argument because it already filters out the mental causation language, formalizing it in a more general way so as to tackle any instance of emergence and top-down causation. It goes as follows:

> If E1 [a higher-level property of an emergent whole] is causally powerful, it can cause some other higher-level property E2 to obtain. [...] Since E1 and E2 are both emergent properties, however, we must suppose that E1 emerges from some basal condition B1, and that E2 emerges from some basal physical state B2. Moreover, since E2 emerges from B2, we must suppose that E2 will obtain whenever B2 obtains, and that E2 will obtain whether or not the higher-level property E1 obtains. There is no way that E1 can cause E2 without bringing about B2, Kim argues, since the only way in which E2 can obtain is by emerging from the basal physical state B2. [... So] why cannot B1 displace E1 as the cause of B2? Recall that E1's causation of the higher-level property E2 presupposes E1's top-down causation of the basal property B2, and that E1 is supposed to emerge from the basal physical state B1. Kim conceives causation as nomological sufficiency. Since B1 as E1's

> emergence base is assumed to be nomologically sufficient for E1 [...], and since E1 as B2's cause is likewise assumed to be nomologically sufficient for B2, it follows that B1 is nomologically sufficient for B2. So we may conceive B1 as its cause [and] E1 [as] causally redundant (30-31).

There is therefore no need to pose E1 as an "intermediate link in a causal chain leading from B1 to B2, and therefore as an ontologically distinct member of that causal chain" (31). And if one wanted to argue that E1 was a top-down cause of B2, that would involve causal overdetermination. As such, emergent properties are precluded from having any top-down causative effect on their own physical basal properties – the threat of causal overdetermination insulates the lower-level physical phenomena. There can be no higher-level causal influence because there is nothing for higher-level phenomena to do. They are, at best, merely epiphenomenal.

Kim's causal overdetermination argument thus strengthens Robinson's position that there is not anything left for structure to do given the causal closure and completeness of physics. And just as Robinson allowed that higher-level (epi)phenomena may figure in our explanations even if they do not constitute to real causes, Kim also provides a "conceptual" interpretation of downwards "causation", arguing that while there might not be a place for it as "real" causation, there sure is as "explanation" (in Tabaczek 2019, 79). For both authors, then, we may appeal to the higher-levels of phenomena but only as mere concepts or efficacious descriptions that ultimately do not track any real causal activity in the world.

In conclusion, if we join Kim and Robinson's arguments, we can put the hylomorphist in a tough position: whereas he wants to argue for the reality of form (or structure) and, as such, both strong emergence and downwards causation (or final and formal causation, in more classical terms), if CCP is true, then any form of causation other than bottom-up physical causation is ultimately redundant. All other forms of causality become superfluous since they will be "overdetermined by distinct individually sufficient synchronic causes" (O'Connor 2020). Not only does the hylomorphist, by rejecting CCP, according to Robinson, renounce our best contemporary science, he does so, if Kim is right, at the cost of also embracing an ultimately inconsistent view of causality.

3. Closing Closure

3.1. The Causal Closure of What?

How can the hylomorphist deal with the argument from closure? Is the fate of form to be rendered obsolete by the threat of overdetermination? Do we have to accept a purely bottom-up account of causation?

In this section, we critically analyze CCP, the principle that lies at the heart of both Robinson's and Kim's argument. The first thing to settle is thus how exactly one should understand it. Usually, that acronym just means "causal closure of the physical". But it is common to also see it stated as "causal closure under physics", "causal closure of physics" or even as the "completeness of physics". Since these diverging formulations can generate confusion, especially on the side of whoever rejects CCP, clarification is welcome.

The meaning of the formulations that mention "physics" are clearer: they refer to the science of physics. But things get harder when it comes to "physical" – and most formulations of CCP appeal to that "physical" – as there is a plethora of senses associated with that word: for instance, "physical" is usually a synonym for material, being thus understood against the "immaterial"; in philosophy of mind circles, on the other hand, "physical" tends to mean whatever is juxtaposed to an equally elusive "mental" – and thus seen as something close to "body" as in the mind-body debate; in philosophy of religion, "physical" is usually equated to the "immanent", meaning the opposite of "transcendent"; sometimes the term means "nature" and even the "natural sciences" as a whole, being contraposed to whatever is "supernatural"; and, finally, there is the sense – which most supporters of CCP work with – in which "physical" broadly means whatever is studied or postulated by physics.

It is important to settle which of these meanings of "physical" CCP is working with, for the semantic plasticity of the word gives the supporter of CCP a chance to play a trick against its critics, imputing on them that, in denying CCP, they must be accepting the opposite of one of the – in this context – non-relevant meanings of "physical": embracing "immateriality", welcoming "transcendence", endorsing the "supernatural" or even outright rejecting the natural sciences as a whole. But these are irrelevant senses of the term because the "physical" in CCP just means physics, the science of physics – and that is how it has been understood and discussed in the literature.

The formulation of closure that makes this clearer is Tim Crane's "every physical event has a physical cause which is enough to bring it about, given the laws of physics" (Crane 2001, 45). By directly mentioning the laws of physics, this formulation clarifies that physical is here equated with physics or what follows from the laws of physics. And that is how we should understand any other formulation of CCP.

So, in rejecting CCP, the hylomorphist is not necessarily embracing mental causation, supernatural causation or anything of that sort, but rather stating that the physical world is not the world of physics – that there is more to the physical than physics can tell.

The Aristotelian simply argues that our grammar of causation must be expanded if we want to get a better grasp on the physical world as a whole. This does not mean that formal and final causation, for example, are to be conceived as "supernatural" or "transcendent", quite the contrary. In the classical Aristotelian sense, the four causes are intrinsic to every natural substance and, therefore, perfectly natural or even physical, depending on what we mean by that term. As such, this is not a quarrel between a truly scientific-minded ontology on the one hand and a pseudoscientific supernaturalist ontology on the other; it is rather an exercise in metaphysics and philosophy of nature, a debate on whether reality is indeed fully captured simply by our "best physics".

3.2. Escaping to the Future

Defenders of CCP thus relegate the exact meaning of "physical" to the dictates of our "best physics". This view of the physical is often labeled "theory-based" since it states that a "physical property is a property which either is the sort of property that physical theory tells us about or else is a property which metaphysically (or logically) supervenes on the sort of property that physical theory tells us about" (Stoljar 2001, 256). This means not only that "if physical theory tells us about the property of having mass, then having mass is a physical property" but also that "if physical theory tells us about the property of being a rock – or, what is perhaps more likely, if the property of being a rock supervenes on properties which physical theory tells us about then it too is a physical property" (256-257).

An obvious problem with the latter part of this theory is that physics never indeed "tells us about the property of being a rock" and even if one manages to show that "the property of being a rock supervenes on properties which physical theory tells us about", it is not clear that this will happen with other things that we would obviously deem as physical. For example, we would not deny that living organisms are physical (in a broad sense) but we are yet to formulate a physical theory that explains how a living organism simply supervenes on properties that physical theory indeed tells us about.

As such, intra-scientific irreducibility is, *prima facie,* a good reason to reject the theory-based conception of the physical. We are far from being able to reduce all scientific explanations to physical ones. One might indeed fancy that everything supervenes on physics, but that is not backed by present physics. The examples of intra-scientific irreducibility are vast, so vast that Weisberg et al. (2019) mention an "anti-reductionist consensus in the philosophy of chemistry literature" while Sterelny and Griffiths (1999, 137) also witness the same "antireductionist consensus" in the philosophy of biology. Various examples of such irreducibility will be given in the course of this thesis. For now, it suffices to say that, as a *present* hypothesis or principle deemed to follow from our "best science", CCP does not hold since we are not able to show that all properties supervene on the properties physical theory alone tells us about. So, if one wants to follow the theory-based conception of the physical, one would have to appeal to a *future* complete physics that would give us a full account on how all properties supervene on the properties studied by physics.

But that does not really save the theory-based conception of the physical. For if the theory means that a physical property is a property that *present* physical theory tells us about, then there are cases of obvious physical properties that are not part of nor supervene on our present physics; and if the theory means that a physical property is a property that a *future/ideal/complete* physical theory will tell us about, then the theory-based view just becomes undetermined (as also noted by Hempel 1980, 194-195).

This line of reasoning has been expanded by Crane and Mellor (1990) who argue that, given the practical impossibility of doing an actual reduction of every other science to physics, proponents of CCP instead argue that such reduction is possible "in principle". But they end up begging the question because applying the reducibility "in principle" "to present physics entails that any future extensions of it would not be physical: that physics, the paradigm physical science, is already complete"; and in applying that same principle to "an otherwise unspecified future physics, we shall not be able to say which sciences are physical until we know which of them that physics must cover – which is just what the principle was supposed to tell us" (188).

So, reducibility to physics, even if "in principle" and abstracted from practical concerns, is not a good way of understanding the "physical". Therefore, when considering the hopes of a "future physics" that might bring to life all sorts of physicalist and reductionistic dreams, we should always remember T. S. Elliot's (1943) sagacious advice: "Fare forward, travellers! not escaping from the past / Into different lives, or into any future".

3.3. Let's Get Physical: The Physical Given in CCP

But does CCP really entail an escape "into any future"? Does not present physics at least point to the reality of CCP? After all, a curious thing to note when discussing the relationship between philosophy and science with physicalists and reductionists alike, is how often they claim their positions be the product of a general "naturalistic" turn in post-Quinean philosophy, that is, a turning "away from the a priori methods of traditional philosophy towards a methodological unification of science and philosophy" (Hacker 2011, 97). It is therefore common to see physicalists argue that their views simply follow from the always very reassuring "best physics" or "best science". But this, as we argue in the course of this chapter, can easily become mere parlance. For it is in no way obvious that contemporary physics affords physicalists the ontological claims they defend.

In fact, even though supporters of CCP claim to do a brand of philosophy that moved away from a priori methods towards a more empirically inspired and informed philosophy, actual defenses of CCP can easily become a prototypical example of speculative and viciously a priori reasoning. And this can be witnessed not only in the deferring of the meaning of "physical" to the intangibly evasive panacea that is "future physics", but also in their treatment of present physics.

Crane and Mellor (1990, 195) argue, as noted in the last section, that "those who claim reducibility 'in principle' either beg the question or appeal to principles [...] which modern physics itself denies". We have seen how they beg the question, now we will analyze how those principles – the unity of science and microreductionism – even though disguised as following from physics, are actually foisted upon it.

These principles are deeply aligned with what Simpson (2020) has called "The Myth of the Physical Given", that is, some views of the physical that even though purported to be "given" by physics, are actually imposed on it by an underlying and usually unnoticed mythology. According to Simpson, the physical given requires:

> i. firstly, the existence of some set of fundamental constituents characterised by determinate physical properties;
>
> ii. secondly, some fundamental state of the world that is closed under physical laws, such that all possible worlds are determined without reference to ends or goals;
>
> iii. thirdly, that this fundamental state should admit a unique representation in terms of our 'best physics', where everything else supervenes upon this physical state. (7)

Even though they do not perfectly overlap, we can analyze i) and ii) on par with Crane and Mellor's microreductionism, and iii) with Crane and Mellor's unity of science. In doing so, we will provide compelling reasons to reject the physical given.

According to Crane and Mellor (1990), microreductionism is the "idea that there is really no more to things than the smallest particles they are made up of" (189). The idea that everything reduces to the smallest particles is, of course, deeply linked to the idea that those smallest particles are all that exists. As such, microreductionism usually goes on par with microphysicalism. In the words of Lewis (1986), a notable microphysicalist:

> all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another . . . We have geometry: a system of external relations of spatio-temporal distances between points . . . And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated. For short, we have an arrangement of qualities. And that is all (ix).

So, in the microphysicalist picture, we have a bunch of physical particles and their possible configurations according to a bunch of physical laws; and that's all. Only the smallest particles exist, with no space for anything else – from the macroscopic to the cosmic scale – be it organisms, tables, persons, or galaxies. This picture, of course, also banishes any form of teleology or goal-directedness from nature since, as Robinson also puts it, all we need is to specify the "spatio-temporal location of the elements and their causal influence on each other", with no need to mention any goals or ends.

But is this picture indeed afforded to us by our best physics? Does microphysics support microphysicalism? The answer is negative and it can be given at various levels. First, as Crane and Mellor (1990) note, "the fact that physics by mere convention includes the study of the very small does indeed trivially entail that everything extended in space either is physical or has some physical parts" (189), but microphysicalism requires one to acknowledge not just that trivial truth, it requires acceptance of the much stronger – and unwarranted – doctrine that only the smallest particles studied by microphysics exist. But on top of giving us no reason to believe that this is true physics goes beyond such microphysicalist constraints by studying "very large things" (189) such as galaxies, quasars, pulsars, black holes, supernovae, etc.

Second, even if taken as a mere methodological position in physics, microreductionism does not hold, let alone when it metastasizes into an entire ontology. For instance, in clarifying CCP, Robinson (2014) states that "physical closure requires that basic physics applies to the basic constituents within complex structures as much as to them when more isolated" (17). It also requires that there is no "perspective of the whole" – that is, rejecting that the whole has any causal efficacy that is not reducible to its parts – and that all real causal activity is purely bottom-up. That is, it requires microreductionism: one might indeed appeal to higher-level factors in our scientific explanations, but those explanations, contrarily to the bottom-up ones, do not track real causes.

The problem is that under this understanding of CCP, not even physics is closed under physics. If real explanations have to follow microphysicalism and appeal to the most fundamental level, one has to ultimately appeal to the most fundamental particle: the quark. However, the theory of quark confinement states that a single quark is never found alone. That is, there are no “free quarks”, they exist only within a larger whole:

> A proton is made up of three quarks, for example, but if you try to separate them you need a great deal of energy and you end by creating more quarks, which combine with the ones you already had to make new protons and other particles. Quarks are parts that apparently cannot exist except in a larger whole (Barbour 1990, 104).

And one can find more similar examples in the realm of physics. For example, the Pauli principle also seems to defy Robinson’s CCP requirements:

> The [sodium] atom is composed of a nucleus of twelve neutrons and eleven protons and has eleven orbital electrons, but none of these acts independently. [...] A "free" electron, for instance, will act only according to its own mass and electric charge, but an electron that is "bound" within the sodium atom “obeys” Bohr's quantum rules [...] The bound electron also follows the Pauli exclusion principle. This principle considers the atom as a whole and specifies that within the atom no two electrons can have the same state (Dodds 1997).

The same goes, as a final example, for superconductivity. The formation of Cooper pairs of electrons arises as a result of the properties of the superconducting material. The presence of lattice distortions within the material allows “electrons that would otherwise repel each other to move as a cooperative unit” (Ellis 2018, 11661). Robert Laughlin jokingly mentioned this example in his Nobel lecture as a testament against reductionism:

> One of my favorite times in the academic year occurs in early spring when I give my class of extremely bright graduate students [...] a take-home exam in which they are asked to deduce superfluidity from first principles. There is no doubt a special place in hell being reserved for me at this very moment for this mean trick, for the task is impossible. Superfluidity, like the fractional quantum Hall effect, is an emergent phenomenon—a low-energy collective effect of huge numbers of particles that cannot be deduced from the

> microscopic equations of motion in a rigorous way and that disappears completely when the system is taken apart.
>
> The students feel betrayed and hurt by this experience because they have been trained to think in reductionist terms and thus to believe that everything not amenable to such thinking is unimportant. But [...] students who stay in physics long enough to seriously confront the experimental record eventually come to understand that the reductionist idea is wrong a great deal of the time, and perhaps always (Laughlin 1999, 863).

It thus seems that even at the most fundamental level, the most fundamental parts can't be understood outside a larger whole. It may be true that sometimes the properties of the parts explain the properties of wholes but that is not always the case, not even in microphysics. What we actually find in scientific practice is a dynamic interpenetration of both forms of explanation. Robinson can of course argue that one may not be able to *explain* a determinate phenomenon without accounting for the whole, but that doesn't show that the whole or structure has any real causal power of its own. As he puts it, structures "contribute nothing over and above the 'forces' of physics, and, as entities, they are nothing above their constituents and their spatiotemporal and causal relations". But this, as Jaworski (2016a) points out, introduces "an asymmetry in the general picture of how explanations are related to causes" (292). That is, Robinson argues that anything operating above the most fundamental level does not map to "causes at all, but [only to] mere explanatory postulates - "parts of explanatory schemes" [...]. What he fails to explain is why we should believe this claim. Prima facie it seems implausible" (291). Its implausibility, Jaworski argues, lies in granting that the explanatory schemes of physics express causes but the same doesn't apply to any of the other sciences. But even at the physical level, Robinson would have to ultimately argue that the proton, for example, is a mere "explanatory postulate" of the quark. As such, given that explanatory schemes in physics also have to appeal to higher-order factors in order to understand the most fundamental level, Robinson will have to ultimately argue that only *some* explanatory schemes map to causes, even in physics. This creates not only an even bigger asymmetry in Robinson's position but also a dilemma: only physical explanations map onto causes, but even in physics, only *some* explanations map onto causes – the ones that refer only to the bottom level and that explain things purely from the bottom-up; however, by referring only to the most fundamental (or lower) level, physical explanations can't really get off the ground.

This means that the physics of microphysicalism is not real physics, but a highly idealized mythology. For real physics does not and, more than that, could not operate under the precepts of microphysicalism. At the same time, these problems tell against iii) – the idea that a fundamental state should admit a unique representation in microphysical terms – because a purely microphysical representation is impossible, even in microphysics. Microphysicalism is thus not *given* by physics, but rather *imposed* on it.

This becomes even clearer when considering quantum mechanics, which provides further testimony against microphysicalism and microreductionism. As Crane and Mellor (1990) put it, if "we take the quantum mechanical description of a quantum ensemble to be complete (as orthodox interpretations do), the superposition principle entails that its properties will not be a function only of those of its isolated constituents plus relations between them. Orthodox quantum physics is not microreductive" (190). This is a point that Simpson (2021, 2022, 2023) continually stresses throughout his work: that quantum mechanics defies microreductionism and the physical given.

Microphysicalists like Lewis see the world as "a vast mosaic of local matters of particular fact" – or properties – captured by physics. But in quantum mechanics, the fundamental description of a physical system is given not by a mosaic of localized and definite physical properties, but rather by a wave function. This wave function offers a mathematical representation of the system in terms of state vectors, which exist in "an abstract high-dimensional configuration space" (Simpson 2022, 7). And unlike the localized and definite properties assumed by microphysicalists, the wave function encompasses a superposition of all possible state vectors. This means that a quantum system can exist in multiple states simultaneously, with each state having a different probability of being observed upon measurement.

The phenomenon of quantum entanglement is also interesting to consider in this context. For, as Anjum and Mumford (2017) note, when "two particles are entangled, they effectively form a causally connected single unit in which, arguably, the numerical identity of the parts has been lost. If we had two electrons, e1 and e2, then once they have become entangled, there might be no fact of the matter about which is e1 and which is e2" (98). On top of that, according to the principles of quantum mechanics, the probabilities of measurement outcomes in different parts of an experiment are also entangled, even when these parts are considered to be "space-like separated" as defined by the theory of special relativity (Simpson 2021, 33). This points, again, to a kind of, at least, methodological holism as, for example, in the famous EPR experiment, the "statistics will depend on the relative angle between the two devices [...]; a fact that neither particle, considered separately, is in a position to 'know'" (33). This certainly does not look like the "vast mosaic of local matters of particular fact" that we should be finding at this level.

But the dynamics of the wave function are also at odds with microphysicalist expectations. A quantum system evolves over time linearly and deterministically according to the Schrödinger equation. So, using that equation, one could predict the evolution of the wave function based on the system's initial conditions. But upon measurement, the wave function collapses, no longer adhering to the Schrödinger equation. That is, before measurement, a quantum system can exist in a superposition of different states – it can be in multiple states simultaneously, with each state having a certain probability – but when measured, the system collapses into one of those states nondeterministically. This tells against not only the microphysicalist "mosaic" – the i) given – but it also defies the idea of closure under physical laws – the ii) given – because the wave function undergoes a discontinuous modification that could not have been predicted by the evolution operator since the Schrödinger equation itself cannot account for the updating of the system that leads to that discontinuous modification (Simpson 2022, 10; 2023, 37).

There is, of course, no agreed interpretation of the collapse dynamic and there are various debates on whether the wave function indeed collapses, if it is caused to collapse, when it collapses, etc. For the purposes of this section, it suffices to say that, even if some interpretations of quantum mechanics try to explain these mechanisms in a way that is amicable to the general microphysicalist picture – excluding higher-level properties and causal powers – they are not settled theories and face problems of their own. The Ghirardi–Rimini–Weber (GRW) theory of spontaneous collapse adds a "stochastic mechanism which produces random 'hits' on the wave function that result in an objective collapse"; and the de Broglie and Bohm interpretation posits a "supplementary guiding equation" that is also not afforded by the quantum mechanics as such. But in both cases, Simpson argues, "the standard textbook theory of quantum mechanics has to be adjusted in rather ad hoc ways to produce a theory which can specify universal laws for the microscopic domain that do not depend upon the existence of a macroscopic 'observer'" (Simpson 2022, 11).

At the same time, there are available interpretations of quantum mechanics that actively defy the assumption that "every microscopic system is closed under the same universal dynamics", the ii) given (11). Drossel and Ellis (2018) have proposed the Contextual Wavefunction Collapse interpretation, according to which "the quantum measurement issue can be resolved by carefully looking at top-down contextual effects within realistic measurement contexts" (1). They thus manage to "derive a wave function collapse process without inserting an ad hoc term into the Schrödinger equation [...] as in other derivations" (Ellis 2018, 11661). They suggest that the collapse of the wave function occurs due to the interaction between the quantum system and the heat bath of a macroscopic system. In this approach, they incorporate stochastic corrections similar to the GRW theory but ground them in the macroscopic context of the quantum system. By introducing a feedback loop from the particle to the intrinsic heat bath of the measuring device and back, non-linear terms are added to the Schrödinger equation. These terms, specific to the system's context, can be accounted for in terms of thermodynamics and solid-state physics, eliminating the need for *an ad hoc* collapse mechanism (Simpson 2023, 39-40). The presence of a macroscopic measuring device at a finite temperature includes a "heat bath with a macroscopic number of degrees of freedom", that is, a system in thermal equilibrium that emits a "non-zero temperature" (Drossel and Ellis 2018). And this measuring device's heat bath is fundamentally classical since it can only be effectively described using statistical mechanics, rather than quantum mechanics. They thus propose that when a particle in a superposition state interacts with a detector's heat bath, its wave function becomes entangled or associated with the heat bath. As a result, the dynamic of the quantum particle is compelled to align with the classical dynamics of the heat bath and this leads to the collapse.

Stressing the importance of top-down effects from the macroscopic context in the quantum realm, Drossel and Ellis introduce stochastic corrections that collapse the wave function without resorting to *ad hoc* insertions in Schrödinger's equation. At the same time, their theory provides a framework for understanding how higher-level properties, characteristic of the macroscopic context, influence the dynamics of quantum systems. Ellis believes that "the interface between the microscopic (quantum) and mesoscopic (thermal) levels offers a pattern for how things work in nature at multiple levels, including the interface between the physical and the chemical and the interface between the chemical and the biological". And he is not alone in this. Aharonov et al. (2018), for example, also argue for "a top–down structure in quantum mechanics according to which higher-order correlations can always determine lower-order ones, but not vice versa" (11730).

This affords us a world where macroscopic higher-level properties have a causal role to play. Contra Robinson and Kim, there is a pattern that we can already start to see at the quantum level, and that fractally expands as we go up, where higher-level phenomena, far from being causally inert or powerless, actually shape the lower-level in novel and unpredictable ways. Therefore, CCP's microphysicalism is not afforded by our best physics but is rather an unwarranted imposition on it.

3.4. Follow the Science

It is thus very far-fetched to say that CCP simply follows from our best science – or physics – or that it is in some way necessary for the development of science. But that is something that its supporters continually stress. Robinson (2021), for instance, seems to think that being inconsistent with CCP is a good enough reason to reject hylomorphism: "What is wrong with a naturalistic hylomorphism? […] I maintain that its significance depends essentially on a kind of downward causation that explicitly rules out such closure [under physics]" (284). A first thing to point out is that this appeal to CCP against the hylomorphist begs the question unless one already accepts CCP. And even if some structural hylomorphists embrace CCP, more classical versions of hylomorphism don't need to accept such principle. Granted, if one accepts CCP, Robinson's argument stands. But he seems to think that his argument tackles even those who reject CCP. And that is because, moving to the second point, his reasoning goes as follows: 1) hylomorphists want their position to be compatible with our best modern science; 2) but that is not possible whilst rejecting CCP. This is a common line of reasoning amongst supporters of CCP. Montero (2003) has pointed out that certain philosophers "have a vague nagging feeling that rejecting CC [causal closure] is somehow being antiscientific" and Papineau (2001) has argued, in a similar vein to Robinson, that science's success and widespread coverage of phenomena serves as the primary source of support for the causal closure hypothesis and that overwhelming scientific progress will make the principle even clearer as time passes.

There is a variety of problems with this line of reasoning and some of them have been tackled in previous sections – such as the "escape into the future" and the idea that CCP follows from, or is given to us by, physics. But a final problem that we should note is that to argue from the success of physics to CCP is, as Feser (2014, 24) has noted, "like arguing that since metal detectors have had far greater success in finding coins in more places than any other method, metal detectors show that only coins exist". Feser's *reductio ad absurdum* shows how unwarranted it is to conclude from the overwhelming success of physics that all of causality must be closed under physics. And this happens with all sorts of inductive arguments for CCP: physics has been extremely successful in investigating certain aspects of reality, but why should we take those to be the whole of reality? Even if one hypothetically manages to show that *taking* all of reality to be closed under physics is indeed a necessary part of a successful scientific methodology, we are not warranted to infer from that that all of reality is closed under physics. After all, an assumption's utility does not guarantee its truth. We should never let a methodological focus become an ontological myopia.

As such, it should be clear that Robinson's implicit move from 1) to 2) is not obvious. In fact, no arguments built on CCP should be taken to be obvious given the plethora of problems we found with it. CCP is not a scientific or (working) methodological principle, it is a philosophical principle that may, at best, be drawn from a certain interpretation of the sciences. So, if the Aristotelian rejects or fails to accommodate CCP, one might only conclude that hylomorphism is not consistent with a specific materialist or physicalist ontology, not with modern science itself.

For CCP continually begs the question for physicalism. For instance, CCP cannot be based on a complete reduction theory of physics because CCP itself is one of the principles which the expectation of such complete reduction theory of physics is built upon (Gabbani 2013, 157). More than that, CCP's rejection of any form of causation other than purely bottom-up microphysical causation is not based on a neutral look at the sciences and nature, but rather the product of an already physicalist outlook on causation. CCP is not discovered by unbiasedly looking at the sciences, it is rather presupposed by its proponents only to be said afterwards to follow from it. CCP's reliance on physics extends beyond determining the nature of physical causation – it aims to define the essence of causation as a whole. By implicitly assuming that only causality within the realm of physics is effective in our world, CCP limits the existence of causes solely to those considered "physical". This leads to the assertion that the world is causally closed, but this closure will simply be a matter of definition rather than a matter of fact (160). That is, all other types of causality are dismissed from the outset. However, by merely excluding them from our conceptual framework, we do not remove them from the world itself. The reductionist approach of CCP thus becomes akin to a Procrustean bed, coercing all phenomena – whether chemical, biological, psychological, etc. – to conform rigidly to an arbitrarily monolithic physical causal scheme. The issue is that this reduction overlooks the inherent specificity of these phenomena when they are reduced to their physical foundations. And, on top of that, it also fails to account for the various cases we mentioned where the higher-level influences and provides new causal powers to the physical level.

Hence, the hylomorphist can indeed believe that his position is compatible with contemporary science without accepting CCP. And if that is the case, appealing to CCP against the hylomorphist will be question begging since what is at stake in the debate is precisely what one means by "physical". Appealing to a concept of "closure of the physical" that is at the outset reductionistic and inhospitable to the Aristotelian is not a valid starting point. The real question at hand is whether the picture of nature depicted by CCP is indeed sufficient to make full sense of our best contemporary science. And we have presented compelling reasons to doubt its adequacy, even within the realm of physics itself.

4. Hylomorphism and CCP

We can now delve deeper into the various versions of hylomorphism and how they deal with CCP. As has been noted, Robinson's criticism is meant to mainly tackle what he calls "modern hylomorphism", that is, structural hylomorphism. In this section, we argue that the closure argument against structural hylomorphism does indeed hold since its proponents either accept CCP or try to give a very minimal account of "structure" that ends up getting caught by Robinson's and Kim's criticism. Those problems provide good reasons to reject structural hylomorphism and embrace a more robust and thoroughly Aristotelian account of hylomorphism: transformational hylomorphism.

4.1 Structural Hylomorphism and CCP

Structural hylomorphists tend to see form as a combination of parts, as a mereological aspect of the matter/form compound (Koslicki 2006), as a relation that grounds embodiment (Fine 1999; Johnston 2006) or as a property or power (as Jaworski (2016a) occasionally puts it). But from a more classically Aristotelian perspective, all of these views suffer from a variety of problems since, in trying to be compatible with CCP, these theories end up falling prey to Robinson's and Kim's argument.

Koons (2014) distinction between "staunch" and "faint-hearted" hylomorphism can be of use here. The core of the distinction is whether or not a given version of hylomorphism can account for the difference between substances such as living organisms and natural kinds on the one hand, and mere heaps of matter on the other (151). According to Koons, in staunch versions of hylomorphism, that difference can be accounted for because "a substantial form is not merely some structural property of a set of elements—it is rather a power conferred on those elements by that structure, a power that is the cause of the generation (by fusion) and persistence of a composite whole through time" (151). That is, the substantial form in staunch versions of hylomorphism has real downwards causal power over its elements and reidentifies them according to the whole. “Faint-hearted” versions hylomorphism, on the other hand, albeit simpler and less ontologically compromised, fail to account for the difference between organisms and mere heaps because they reject some of the key features of a more classical hylomorphism.

Koons mentions Johnston’s theory as a prime example of a faint-hearted hylomorphism. According to Johnston (and the same could be said of Fine), composite hylomorphic entities should be understood in terms of some parts being in a relation that unifies them (155). But that unqualified theory leads to the rather bizarre conclusion that any collection of entities in some relation counts as a whole: “a whole consisting of your eyeglasses and Pluto [...] is fully, completely and genuinely true that it is a whole” (Johnston 2006, 697). This, of course, cannot provide us a robust difference between organisms or natural kinds and mere (even conceptual) heaps.

A similar problem is to be found in Koslicki’s version of hylomorphism, according to which form is a mere combination of parts, a mereological aspect that is just the structural arrangement of a determinate matter. Even if more constrained than Johnston, this theory still fails to provide a more robust account of form. In fact, that structure is just the arrangement of matter is the very target of Robinson’s argument. But as Robinson shows, given the mereological conception of matter that Koslicki is working with, there remains nothing for form – or structure – to do here.

And the same could be said of Jaworski’s theory – the one that Robinson spends the most time dealing with. Jaworski (2016a) explicitly accepts CCP (292) and rejects top-down causation (280-285) while trying to argue that living organisms possess irreducible causal powers (7; Jaworski 2016b). This is, of course, a very difficult – if not impossible – task and Robinson makes that very clear in his criticism. For if one accepts CCP and rejects that structure has any real causal power, what is, again, structure really supposed to do? This becomes even harder to square when Jaworski (2016a, 29), in the course of his argument, upholds the Eleatic principle, according to which something has being if it can bring about changes in the world, that is, if it has causal power. But how can structure be real and irreducible if it is causally impotent? Jaworski tries to deal with this by identifying explanatory irreducibility with causal irreducibility thus salvaging structure from physicalist reductions (in Simpson, 2023, 33). But it is impossible to build on that identification whilst upholding CCP. Kim and Robinson show that CCP requires a sharp asymmetry between causes and explanations. Kim's argument in specific makes it manifest that, given CCP, all of causality must happen only at the basal level, at the cost of overdetermination. As such, above the basal level, there is no real causal irreducibility. So, identifying explanatory irreducibility with causal irreducibility would do no good to salvage structure or the specificity of living organisms, for example.

In all of these cases, the broader problem is what Koons (2014, 153) has called the "statue fallacy", "taking Aristotle's statue analogy in Physics II.3 and Metaphysics V.2 as providing a literal example of material and formal causes". There, Aristotle says that the form of the statue is its shape. But Aristotle makes it clear in other passages that a statue can only be said to have a substantial form in a loose manner. For it would be strange to say that, as we will see in the next section, the configuration of the statue has a capacity for "statueness". The statue has an accidental unity, not a substantial unity. It does not display the dynamicity of a real form, the capacity for self-actualization, the inherent teleology, or the ability to guide and organize the development and behavior of its material constituents. That is because Aristotelian substances are not mere shapes or configurations, but dynamic principles that imbue substances with their unique properties and capacities.

We must then go past structural hylomorphism and embrace a more classically inspired version of hylomorphism, one that provides us with a good way of distinguishing real substances from mere heaps of matter, all whilst avoiding the threat of causal overdetermination and CCP. This is made possible, we will argue, by adopting a form of transformational hylomorphism that, in embracing both strong emergence and downward causation, provides a thorough account of how forms can be causally potent whilst avoiding CCP and the problem of causal overdetermination.

4.2 From Structural to Transformative Hylomorphism

In a more thoroughly Aristotelian sense, form is better understood as a principle that re-identifies the material parts of a whole (Marmodoro 2013, 16-18) or as an irreducibly holistic principle of specificity of a thing (that by which it is what it is) (Oderberg 2007, 65). These can be called transformational accounts of hylomorphism because they argue that, when caught up in a substance, the parts are reidentified – or transformed – according to the whole of the substance.

The first thing to note is that a substance, in contrast to a heap, is a unified whole. As such, it is wrong to think of matter and form as parts of a substance – like Koslicki – since a form is not something added to a substance's matter but rather its very unifying principle. And the way a form acts as a unifying principle is by reidentifying the material parts of a whole according to its identity. As Marmodoro (2013) puts it, the parts of a substance exist in it "holistically", having no "distinctness" in the substance.

A second thing to note is that transformational hylomorphism rejects some of Robinson's and Kim's (and even some structural hylomorphists') crucial assumptions regarding causality. Their arguments are nested within a broadly Humean view of causality that considers event-causation – of separate and innately disconnected events – to be the only form of causation. Transformational hylomorphism, on the other hand, embraces a form of powerism according to which powers are fundamental and irreducible properties (on par with categorical properties); accepts that there is more to causation than mere event-causation – substance-causation, for instance; and considers causation to be not only a matter of events but also processes with "intrinsically connected stages" (Mayr 2017, 77). And crucially, transformational hylomorphism also rejects the assumption that causality is a full-on diachronic matter. Following Mumford and Anjum (2011), it rejects the temporal priority of causes over effects understanding instead that, in various cases, causes and effects are simultaneous. For instance, standard accounts of causality take that first the floor gets wet and then someone slips on it. But that is not a good representation of the occurrence. For the "causing of someone slipping occurs only at the time that someone is walking upon the wet surface. The slipping must, then, be simultaneous with the wetness" (Anjum and Mumford 2017, 100). The cause of the slipping is the wetness. Whatever made the floor first wet may be an explanation of why the floor got wet, but is not the cause of the slipping.

This enriched – not only diachronic, but also synchronic – view of causality can help us make better sense of vertical forms of causation. This is especially helpful for the transformational hylomorphist, who ultimately argues that the best way to understand the relationship between the form and the matter of a substance is by synchronic downwards dependency, according to which the whole transforms its parts.

And therein lies the critical difference between mere structural and transformational hylomorphism: in structural accounts of hylomorphism, the parts to get structured have the same "force-generating powers" that they had previously to getting structured. That is, they possess the same powers when "in the wild" and when in a substance (Simpson 2023, 43). The transformational hylomorphist denies that. What happens – and this is something that the structural hylomorphists on par with Kim and Robinson can't account for – is that some cases of structuring, some rearrangements of parts are more interesting than others. But why? Because in some cases strong emergence occurs: new powers emerge from the interaction of the transformed parts. Several examples of this phenomenon have been provided in the previous sections: for instance, the Pauli principle, where the behavior of a "free" electron deeply changes when "bound" or the formation of Cooper pairs of electrons where "electrons that would otherwise repel each other [...] move as a cooperative unit". These are all examples of a qualitative change of the elements when entering into a whole, not just a mere aggregation of powers. For instance, water has the power to extinguish fire even though composed of two, when not caught up in the whole, highly combustible elements. What happens in these cases cannot be fully captured by structural accounts because "the concept of structure presupposes the properties of the parts which play a role within the structure" and as such "cannot explain the transformation of those parts" (43).

The transformational hylomorphist thus contends, contra CCP, that "the indeterminate powers of the lower-level parts of a substance, considered apart from the substance, are never sufficient for determining the facts about where the matter ends up" (43). And this is why Kim's argument does not hold: it relies on the shadows cast by the higher-level onto the physical level, whilst being incapable of noticing that they are dependent on that which casts them. The crux of the causal overdetermination argument is showing that the causal powers of the basal level are completely independent of the macro-level and that, as such, any whole could be decomposed without any loss to just an aggregate of its basal level properties or powers. The reason the argument fails is that higher-levels introduce novel, irreducible, and – from the basal level – unpredictable causal powers. Remembering Laughlin's Noble lecture, the fractional quantum Hall effect, for example, "is an emergent phenomenon—a low-energy collective effect of huge numbers of particles that cannot be deduced from the microscopic equations of motion in a rigorous way and that disappears completely when the system is taken apart". Contra Kim the higher-level is not redundant: neither methodologically – because we need "the higher-level entities in order to single out their relevant 'surrogates'" – nor ontologically – because those "surrogates" get their identity from the whole (Paoletti and Orilia 2017, 5).

This transformational account of hylomorphism also provides us the tools to deal with another problem rightfully noticed by Kim concerning emergence: that it is more often than not defined in purely negative terms (an emergent property is not reducible to a basal property, for example). But, following Mumford and Anjum, the transformational hylomorphist can provide a positive account of emergence and downwards causation – or what they call demergence – in powerist terms. According to their formulation, "emergence is where there are new powers of wholes in virtue of causal interactions among their parts; demergence is where there are subsequent new powers of the parts in virtue of the causal action of the whole upon them" (Anjum and Mumford 2017, 102). On top of providing a positive account of emergence and downwards causation, Mumford and Anjum's theory is also amicable to the general hylomorphist project because they embrace a transformational take on their ontology of powers, arguing that a phenomenon is emergent if "through their interaction the parts undergo a change from which the whole they compose has a new power" (105). This also provides an interesting distinction between mere heaps and substances: in the case of heaps or mere aggregation of parts, contrarily to what happens with substances, we do not find the emergence of powers of the whole that were not possessed by its parts "in the wild" nor do we find there "demerged changes", that is, downward causal influence from an emergent power to the lower-level parts.

With all this in mind, we propose that a better way to understand form is as an irreducibly holistic principle of specificity of a thing (that by which it is what it is) that dynamically re-identifies the material parts of an entity towards the same end as a singular causal system. The best way to understand the nature of emergence and downward causation is, we argue, by grounding it in the concept of form. Emergents should be understood in relation to the acquisition of new substantial forms by more complex or higher-level entities such as chemical compounds, substances, and organisms, that is, the novelty of properties exhibited by emergent entities or dynamical systems stems from the unique substantial and accidental forms inherent to them (Tabaczek 2019, 250). In this account, form is thus not just a "privileged sort of property whose causal operations bring together an entity's otherwise mereologically disparate parts" (Tabaczek 2023, 24) but instead the very activity of (in-formed) matter.

Following Austin (2020), we argue the distinction between matter and form is better understood as grounded in the metaphysical distinction between "capacity and activity, or organ and operation" (115). This affords a better account of why artifactual or accidental forms are only analogous to real substantial forms. As Austin puts it, artifactual forms, like the statue previously mentioned, "aren't the exercise of any powers of that matter: there is no sense in which, for instance, the 'architectural configuration' of a house constitutes the activity of its constituents; the stones and bricks don't possess capacities for 'houseness'" (117). There is no strong emergence nor downward causation here, the parts don't get any new powers by getting caught up in that "whole", that is, they are not holistically transformed. What happens is simply a matter of aggregation. But things are different in the case of real substances: for instance, when

> a fox dies, what remains is not the body, or matter of the fox [...] even though there may remain a perfectly preserved, structurally intact organic mass, there now exists *nothing which has the capacity for foxiness*, nothing which is potentially fox-ing – that is, nothing which could actively generate the functionally integrated and homeostatically maintained organismal system by which the 'way of life' (the bios) particular to foxes is carried out (116-117).

The example of the fox, which echoes various similar examples by Aristotle, gives us important insights into the nature of form. The corpse of the fox "may remain a perfectly preserved, structurally intact organic mass" – a fresh corpse may even maintain the same low level of physical entropy that is characteristic of life –, that is, it might keep all the material components and structure it had when the fox was alive. But something was lost when the body of the fox became a mere corpse. And what was lost – the form of the fox – is as such not capturable at the level of its mereological constituents. Hence, form is not a property or an extra-mereological feature of things but rather what grants the unity and metaphysical oneness of substances beyond "mere togetherness" (Austin 2018, 187). Formal unity implies not only strong emergence and downwards causation in the sense that a substance performs higher-level activity that depends on its parts "operating in causal unison", but also that all these parts work holistically towards the same "causally privileged end, or ends" (187). And that is what ceased to happen when the fox died and what is absent from mere heaps and other accidental unities.

With this, we are, of course, not only reinstating form but also what Robinson (2014, 18) deemed to be an "embarrassing feature of the Aristotelian system": teleology. However, as we will see, teleology is not just an artifact of outdated ways of thinking but rather a growing part of the grammar of contemporary science, especially contemporary biology.

5. (In)Formed Biology

The metaphysical picture of hylomorphism provided in the last section has three great virtues – that also make it more in line with the classical Aristotelian picture of hylomorphism: first, it accounts for the fact that the parts of a substance are said to exist only in the substance – to use the classical example, the detached hand is a hand only 'homonymously'; second, it preserves the unity of the substance by showing that substances cannot have substances as parts; and third, it provides us a better way to understand the dynamicity of substances such as living beings.

It is on this third aspect that we will focus on in this last section. Drawing on what has been said before about the quantum realm, physics, and chemistry, we will now look at the biological realm and provide a glimpse of transformational hylomorphism's picture of nature. This, we will argue, is way more in line with contemporary science than the purely bottom-up picture of nature presupposed by CCP and its proponents. At the same time, it avoids the usual accusations against Aristotelianism: for instance, that its essentialism and commitments to substantial forms render nature stagnant, fixed, or unchanging.

As we have noted, one of the key features of actual substances, such as living organisms, is their dynamicity. The Aristotelian is thus ready to accept that organisms differ from heaps and artifacts in being "processual things" (Walsh and Wiebe 2020, 109) that are subject to continuous material change nevertheless maintaining their unity and identity over time. And it is in accounting for this continual and dynamic process of maintaining the same unity and identity over time whilst undergoing various changes that the previously exposed grammar of causality shines the brightest. By understanding the profound interplay of strong and downward causation within living organisms, which involves the mutual, continuous, synchronic, and diachronic interaction between bottom-up and top-down levels towards the same singular informed end, we not only gain a deeper comprehension of contemporary science but also a richer picture of nature.

So, what does it mean to say, with Walsh, that organisms are "processual things"? As John Dupré (2013) incessantly points out: "a static cell is a dead cell" (30). To live is to be "actively engaged in life-processes that mutually sustain and enable each other" (Mulder 2021, 34). But these life-processes are not discrete and disparate occurrences but rather "always embedded in, and thus unified by, the whole life cycle of which they form part" (35). To go back to Aristotelian terminology, all these life-processes point to the (life-)form of the organism: it is because of its form that those processes occur in the way they do, in the order they do. It is this (life-)form that provides a unity to a living organism beyond mere togetherness: because all life-processes work in causal unison towards a unified causal goal, the maintenance of the organism.

Organisms display, to use a scholastic-inspired terminology, immanent causation: "causation that originates with an agent and terminates in that agent" for its own sake (Oderberg 2017, 211). In more scientific terminology, we could say that living beings are "autopoietic systems", systems that can reproduce and sustain themselves; or "teleonomic", that is, goalseeking systems (Ellis 2008). In both cases, we are bound to use teleological language, to appeal to Robinson's "perspective of the whole". We have seen that such perspective is hardly eliminable even in physics, but it becomes even more exceedingly crucial in biology. For it is within the whole life-form of the organism that we must understand its physical and chemical processes, it is only then that those processes make sense. At the various levels of organization – from the gene to the cell, from organs to the entire organism – organisms display an impressive multiple realizability of higher-level functions, that is, various ways of achieving the same higher-level function or process by a variety of lower-level variables and paths. In these cases, what we find is that the lower chemical or physical level becomes a "tool" of higher-level organization, shaped according to the higher-level ends of the whole organism.

Denis Noble, one of the pioneers of systems biology, has shown this extensively in his groundbreaking model of the heart. Noble (2012) has argued that, no matter how impressive the reductionistic agenda has been in biology, if the general reductionistic view is to be justified, “we need empirical evidence that information that could be regarded as ‘controlling’ or ‘causing’ the system only passes in one direction, i.e. upwards” (56). And that is exactly what some deem to be “the central dogma of molecular biology”, first stated by Francis Crick in 1957, that DNA makes RNA, and RNA makes protein. If that is correct, then all of causality in biology goes in one direction, from the bottom upwards. But as Noble shows, such “dogma” rests on a number of misconceptions: it sees the genetic program as coding proteins *simpliciter*, but the very idea of a genetic program is misleading. The “genome is not a fixed program” but rather “a ‘read–write’ memory that can be organized in response to cellular and environmental signals” (57). This means that there is no full bottom-up determination. The complete specification of which proteins and RNAs are produced, as well as their timing and location within an organism, remains incomplete: “This is why it is possible for the 200 or so different cell types in an organism such as the human to make those cell types using exactly the same genome. A heart cell is made using precisely the same genome in its nucleus as a bone cell, a liver cell, pancreatic cell, etc.” (57). Noble argues that the regulatory circuits of a genetic program during development cannot be considered separate from the cellular, tissue, and organ-specific programming that epigenetically controls the genome and regulates the appropriate patterns of gene expression for each cell and tissue type within multicellular organisms (57). He thus compellingly states that the genome, by itself, is never sufficient:

> DNA sequences do absolutely nothing until they are triggered to do so by a variety of transcription factors, which turn genes on and off by binding to their regulatory sites, and various other forms of epigenetic control, including methylation of certain cytosines and interactions with the tails of the histones that form the protein backbone of the

> chromosomes. All of these, and the cellular, tissue and organ processes that determine when they are produced and used, 'control' the genome (57).

We can use Noble's own model of the heart as another example of all these processes (p 57-61). Noble's groundbreaking model shows that the heart rhythm is a multi-level phenomenon involving interactions between various components, including ion channels, cell membranes, proteins, and the overall cellular structure. These components are interconnected and influence each other in a feedback loop. The activity of ion channels, which regulate the electrical potential of the heart cells, is controlled by the cell potential itself. In turn, the cell potential is influenced by the gating of ion channels. This multi-level loop known as the Hodgkin cycle is crucial for maintaining the rhythm of the heart. A curious thing that the model demonstrates is that disrupting the feedback between the cell potential and the gating of ion channels abolishes the rhythm. Even though the genes encode the proteins involved in cardiac rhythm, the genes alone do not generate the rhythm; it rather emerges from the interactions and constraints imposed by the higher-level structures, such as the cell itself and its membrane system.

This, again, challenges reductionism because it indicates that understanding the cardiac rhythm requires considering not only the genetic level but also the higher-level structures, cellular interactions, and environmental factors. More than that, interrupting this feedback loop, which represents the downward causation from the global cell property (cell potential) to the protein-level parameters (ion channel gating), abolishes the rhythm (57). This implies that the rhythm is not simply a result of a sub-cellular program or the activity of individual genes but rather an emergent property that, arising from the interactions and constraints imposed by the higher-level structures and processes, cannot be fully explained or predicted solely based on the knowledge of genes or genetic variations.

Noble thus concludes that

> to think that the genome completely determines the organism is almost as absurd as thinking that the pipes in a large cathedral organ determine what the organist plays. Of course, it was the composer who did that in writing the score, and the organist himself who interprets it. The pipes are his passive instruments until he brings them to life in a pattern that he imposes on them, just as multi-cellular organisms use the same genome to generate all the 200 or so different types of cell in their bodies by activating different expression patterns (57).

This analogy may seem faulty: is Noble arguing that a kind of biological homunculus is working like an organist inside all organisms? Is he presupposing a kind of extra-physical vitalistic force that makes, to continue the metaphor, the music play? Not at all. Noble recognizes that, in the case of organisms, there is no organ player, there is no conductor to the music: "the 'music of life' plays itself" (Noble 2008), to use his beautiful formulation. And this is where hylomorphism shines the brightest. Teleology is, as we have noted, completely intrinsic to substances. There is no extrinsic or quasi-physical vitalistic force at play here, making the elements conspire to form their intricate order. There is no ghost needed in the machine because hylomorphism simply ceases to see organisms as machines. The Aristotelian grammar of causation gives the tools to understand these complex phenomena without having to appeal to any of those. What we have is instead examples of the formal unity of the organism with all its parts working in unison and dynamically determining the lower physical parts towards the same goal, the dynamic interplay of top-down and bottom-up causation that is unified by the substantial form characteristic of organisms.

But Noble is not an isolated case. This same anti-reductionistic and holistic move can be witnessed in other areas of biology, for example, in evolutionary developmental biology (or evo-devo). Evo-devo emerged as a reaction to the "Modern Synthesis" which dominated biology for a great part of the 20th century. This Modern Synthesis basically conjoined Darwin's theory of evolution with Mendel's studies on heredity into a single mathematical framework. The result was "population thinking", a methodological focus on groups rather than individual organisms. These populations were in turn conceived as "gene pools" whose evolution, diversity and morphogenesis could be understood in terms of quantitative mathematical models tracking the distribution of genes in a given genetic pool across time. This meant that "the goal-directed morphogenesis of organismal features was no longer an intractable and inexplicable phenomenon" but rather "nothing more than the adaptive by-product of undirected populational variation and a mere reflection of selective pressures filtering the random rippling of gene pools" (Austin 2021, 243). The Modern Synthesis thus took morphogenesis to be a "fundamentally extra-organismal affair" (243) that led to the belief that "... one needed only general statistical laws about the interactions among individuals, rather than specific knowledge of the individuals themselves, in order to determine the effects of evolutionary mechanisms" (Morrison 2000, 215).

The Modern Synthesis is closer to Robinson's and Kim's CCP picture of nature. It not only takes a purely bottom-up explanation of biological phenomena but also frames all glimpses of goal-directedness in nature as an accidental by-product of the organisms being passively pushed and pulled by selective evolutionary pressures.

According to Walsh (2006), the Modern Synthesis is inhospitable to the Aristotelian

> (i) in its ontology – modern synthesis biology treats populations as assemblages of Mendelian trait types, not of organisms; (ii) in its explanatory apparatus — changes in population structure are explained not by the causal powers of entities of some kind but by the statistical structure of populations; (iii) in its conception of the source of variation (434).

But the Modern Synthesis has been increasingly questioned over the last few decades. Recent trends in biology such as evo-devo and systems biology have come to realize that the drift and flow of genetic variation, which serves as the raw material for selective processes, exhibits inherent biases and probabilities, that the morphological pathways of organisms are not merely the result of extrinsic forces acting on them, and that there are limitations and constraints on the range of possibilities for organismal morphology, as observed in the stability of morphology throughout a population's evolutionary history (Austin 2021, 243). That is, organisms came to be seen as more than inert artifacts shaped by the selective process and determined purely from the bottom-up.

Austin and De La Rosa (2018) describe four basic tenets of evo-devo but, for our present purposes, we will only focus on two of them: robustness and plasticity. As they put it, robustness "refers to the ability of developmental trajectories to buffer against environmental or genetic perturbations that would otherwise affect a phenotypic outcome" (5). This means that "robust systems are both persistent – able to maintain the causal production of an end-state by means of compensatory changes within the system – and pleonastic – able to bring about that end-state via a number of alternative pathways" (5). This is directly tied to plasticity as the "ability of organisms to produce distinct phenotypes in distinct environments" (6).

Both of these tenets are paradigmatic cases of goal-directed activity. According to Walsh (2006), a system has a goal when it "has the capacity to reach its end-state by a number of alternative pathways" (441), and that is exactly what the plasticity and robustness of organisms point to.

But is this "embarrassing" teleology actually eliminable? Can we reduce the robustness, and plasticity of organisms to mechanisms (ontogenetic, for example) and explain them away in just bottom-up terms? We have good reasons to think not.

In order to perform a mechanistic reduction of organisms, we would have to perform a successful "decomposition" and "localization", that is, we would have to define them as structures that perform functions based on solely their component parts, operations, and organization (Austin 2021, 248); and, in breaking them down to their discrete elements, we should assign a unique functional role to each element. However, Austin argues that successful models in biology, particularly those based on dynamical systems theory (DST), present a different perspective. These models represent the process of development as a continuous series of transitions between entire system states, rather than a step-by-step progression of isolated elements (249). DST models capture the developmental constraints and privileged permutations of organisms by considering the topological curvatures of the system's state space (251). It is from these models that biologists capture the robustness and plasticity features of organisms. But are these mechanically reducible? Austin thinks that such reduction in terms of decomposition and localization is not plausible because the topological structure that underlies these features is not itself "a compositional element of an ontogenetic system, or strictly reducible to any such element (or set thereof)" (252). What we find is instead "a set of comprehensive whole-system states which form a continuous and exhaustive mapping of every available iteration of the values of those states" that is not "a proper part of such systems or capable of being discretely anatomised into [its] modular elements" (252).

In Aristotelian fashion, one could say that the plasticity and robustness exhibited by organisms are grounded in the whole, not in the component parts of the organism. As system-level features that can't be reduced to any of the parts of the system, they are byproducts of its formal unity. As we have seen before, a form dynamically re-identifies the material parts of an entity towards the same end as a singular causal system and that is exactly what we find at the biological level. The parts lose their identity when caught up in the whole, it makes no sense to take them as discrete and independent elements, which is what we also find at the biological level.

It turns out that the old Aristotelian idea of form – as that which "actively generate[s] the functionally integrated and homeostatically maintained organismal system by which the 'way of life' (the bios) particular to [an organism] is carried out" (Austin 2018, 187) – seems to have a place of its own in contemporary science.

6. Two Pictures of Nature

In the course of this thesis, we have been looking at two very different pictures of nature. The first picture, which we might call "microreductive", was provided by CC This picture relies on the "vast mosaic" of local matters of fact that, in its various assemblages, gives rise, in a purely bottom-up way, to all there is. This means that whatever one finds above the microphysical level is ultimately causally inert, incapable of bringing any real change in the world for, in this picture, there are no genuine wholes that cannot be perfectly reduced to their parts.

At the heart of this picture lies, of course, Kim's causal exclusion argument. If we follow it, we have to acknowledge that the higher-level is bound to be redundant, a mere conceptual mirage that does not reflect any real causal happening. With this, teleology becomes nothing but an artifact of ancient quasi-magical ways of thinking, long proved wrong by modern science.

This picture seemed coherent, explanatorily successful, and, above all, extremely parsimonious. But as we zoomed in, we started to notice that its parsimony came at a cost: there were various blind spots in the picture. Firstly, these deficiencies were atoned by a deferral to the future. The picture may yet not be complete, but it will certainly be in the future. But we noticed this to be rather strange. Proponents of this picture hailed it to be perfectly scientific, the product of a naturalistic turn in philosophy: why were they, all of a sudden, appealing to "a conviction of things not seen"? That became clearer as we kept zooming in. This picture was not in fact *given* by science but instead *imposed* on it, like a procrustean bed, squishing the richness of phenomena in a monistically crude causal framework.

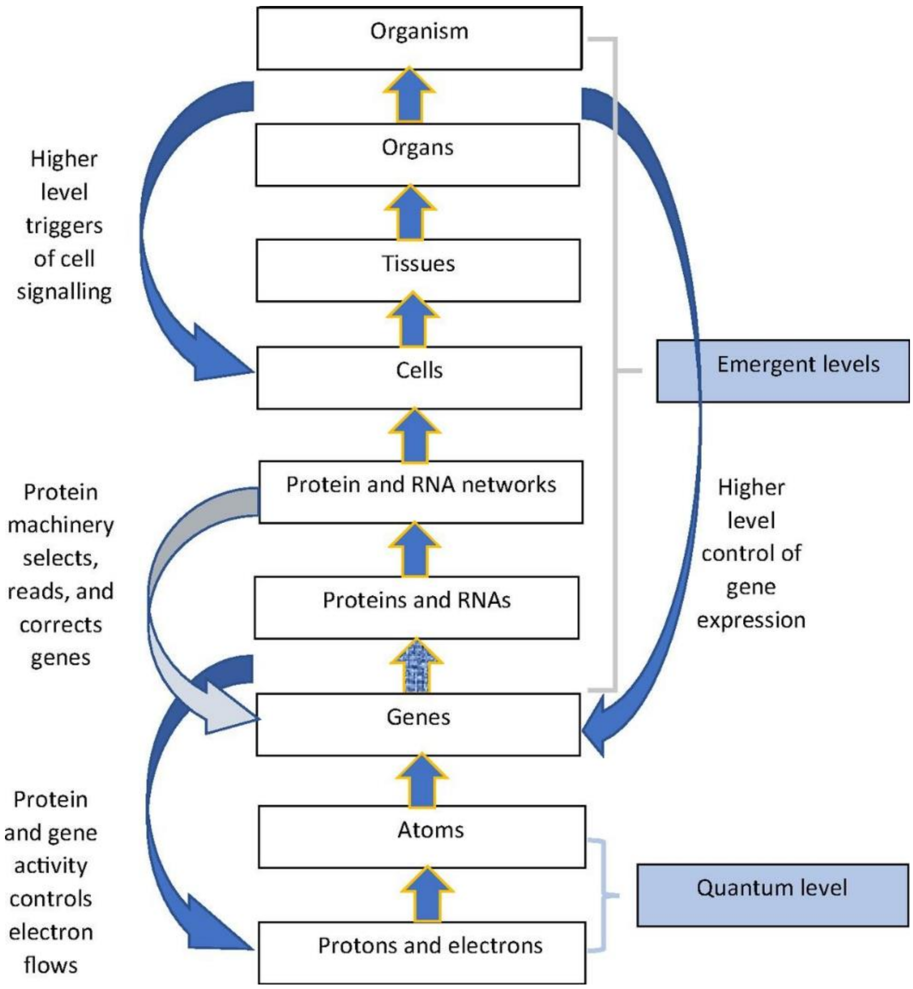

Figure 1 (in Ellis 2018)

What we found when looking at contemporary science was something that this picture could not afford us: the need for a more dynamic view of causal interaction where the merely bottom-up approach is not sufficient. By considering various examples from physics, from superconductivity to quantum mechanics, we started to notice that microphysicalism does not apply even in physics. Contra Robinson and Kim, we discovered that contemporary physics affords us a world where macroscopic higher-level properties have a causal role to play. And what we saw at the quantum level fractally expanded as we went up, as higher-level phenomena, far from being causally inert or powerless, actually shaped the lower-level in novel and unpredictable ways. This became clearer when considering various developments in contemporary biology. Therefore, CCP's microphysicalism is not afforded by our best science but rather imposed on it.

To use Wittgenstein's expression, we could say that microreductionism holds its supporter's captive. For it makes its supporters myopic, incapable of looking upwards beyond the bottom-up methodological focus that is indeed sometimes necessary in science. What the picture afforded by CCP misses, considering figure 1, is that there is more to nature than the merely upward-pointing arrows. Of course, this reduced picture may have been extremely successful and purely bottom-up explanations will always capture a great deal of truth. But it is wrong to take the bottom-up aspect to be encompass the whole of reality. In doing so, one is bound to gaze at shadows whilst being incapable of noticing that which casts them.

When we considered the Aristotelian hylomorphist picture of nature, what we found was something much more amicable to this dynamic, both bottom-up and top-down, picture of nature afforded by contemporary science. With its reliance on form, teleology, and substantial unity – that can ground the contemporary categories of top-down causation, for instance – hylomorphism already offered us a more enriched view of causation. Contra Robinson and Kim, we considered various instances of strong emergence, where new powers of wholes emerge in virtue of the of causal interactions among their parts; and downwards causation, where the parts also get new powers in virtue of the causal action of the whole upon them. These refuted the reductionist notion that the whole can be fully reduced to its parts without any loss, for in fact, by neglecting the substance as a whole and focusing solely on its component parts, important insights about the parts themselves are missed.

If CCP provided us a reductionistic picture of nature, Aristotelian hylomorphism provided us with a holistic picture of nature where macroscopic objects are granted real existence and causal influence in the world. This became even clearer when we considered recent developments in biology where, considering again Fig. 1, the work of the downwards-pointing arrows become more obvious. And there, teleology also ceased to be a mere artifact of ancient ways of thinking.

We thus conclude that, contrary to what Robinson thought, it is not true that hylomorphism does not “fit nature as we now understand it”. In fact, it is CCP that is an artifact of outdated reductionistic dreams. For concepts such as “emergence” and “downwards-causation”, “autopoiesis” and “teleonomy”, just to give a few examples, are a growing part of our scientific grammar. And all of them defy understanding in the microphysicalist reductionist terms CCP requires, whilst easily fitting in the general hylomorphic picture of nature.

By relying on the shadows cast by substances, CCP may indeed capture a great deal about reality. But without accounting for the whole, there will always be a hole in its explanatory apparatus. And if we want to cover it, we must go past the shadows.

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