

# Ontological and methodological virtues of unification

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**Abstract.** The widespread mistrust of metaphysics—the main obstacle to the unification of physics and philosophy—is based on the myth that metaphysical claims cannot be falsified or verified, because they are supposedly true independently of empirical knowledge. This is not true of *metaphysical naturalism*, whose approach is to critically reflect on the theories and findings of *all* the empirical disciplines and abstract from them a theory about such general features of reality that no single empirical discipline can be the authority on. Causation is such a feature, since its instances include anything from planetary motions to particle interactions, chemical reactions, biological functions, and closing a door. Consequently, a general account of causation is beyond any particular empirical discipline. Metaphysical naturalism takes a meta-perspective on the results of the empirical sciences and attempts to figure out how it fits together in a coherent whole, e.g. by offering a general account of causation. General accounts of this kind are falsifiable in so far as the theories are falsifiable from which they are generalizations. The paper also discusses some fundamental metaphysical principles implicitly assumed by the sciences generally, and why they imply that unification is methodologically virtuous.

## 1. Introduction

This paper represents my two cents worth about the virtues of unification, with a special focus on metaphysics and physics. Observe that I have nothing against specialisation and accept that the *strive* towards fragmentation that ensues from specialisation has its role to play too in our collective endeavour to understand the world. I only argue that science as a whole should not forget to also strive towards unification. Let us appreciate the benefits of a division of labour. Some take a narrow and specialised focus on particular phenomena while others take a big-picture approach to bringing together the results from the specialists into one coherent whole. Like many of the contributors to this issue, I worry that the balance is tipped too much in favour of specialisation and that this brings with it a negative kind of fragmentation. I might be wrong to worry, but it doesn't hurt to become clearer on the nature and value of unification.

There are three parts to my contribution. I first argue (§§2–3) that the widespread mistrust of metaphysics is misplaced. A myth has been created about the nature of metaphysics, and the critics have worked ceaselessly to spread the gospel about its dangers; mainly that metaphysics is nonsense and turns everything it touches to nonsense. This mistrust comes largely from the mistaken belief that all metaphysics is *a priori metaphysics* (APM). The deficits of APM are discussed and I present an alternative view, *metaphysical naturalism* (MetNat), which empirical researchers should not have any qualms about. The moral is: don't judge the whole bushel by a couple of bad apples.

Second (§4), I draw attention to a number of metaphysical principles concerning the nature of



material reality, that for a very long time have functioned as methodological principles in our endeavours to understand the world, both in philosophy and physics [1-3]. My argument is that they are not *a priori* principles, that they are widely assumed in the natural science (if only implicitly) and they imply that unification is virtuous. Finally (§5), I illustrate the potential of MetNat by showing its application to the issue of causation.

## 2. The mistrust of metaphysics

There is a widespread mistrust of metaphysics among philosophers and natural scientists alike (see, for instance, [4-7]). The term ‘metaphysical’ is often used to denote whatever anyone considers fantastical or nonsensical. This mistrust sometimes manifests itself in the kind of devout hatred that is characteristic of dogmatic fanaticism. Here is Otto Neurath, a core member of the Vienna circle, recommending that we get rid of metaphysics by indoctrinating children with a metaphysics-free language:

We shall, from the very first, teach children the universal-slang—purged of all metaphysics—as the language of the historically transmitted unified science. Each child will be so trained that it starts with a simplified universal-slang, and advances gradually to the use of the universal-slang of adults. [5]

Metaphysics is evidently so bad we make sure the innocents are never exposed to it, because the risk is they might disagree with the teachings of the Vienna circle. To be sure, individual metaphysicians have created positions that are fantastical and ‘out there’, but you come across that in every academic discipline. Why should metaphysics be singled out as particularly prone to produce such ideas?

I think it boils down to the widespread myth that metaphysics is essentially an attempt to discover the ultimate structure of reality *only* by means of arguments that are valid prior to and/or independently of experience, and thus also of the theories and findings of the empirical sciences; ‘experience’ is here assumed to include what counts as observation/measurement in the empirical sciences. Today this form of metaphysics is labelled *a priori metaphysics* (APM), to distinguish it from other approaches to metaphysics; clearly, all metaphysics is not of the same kind.

Undoubtedly there are certain forms of *a priori* knowledge, e.g. mathematics. We don’t confirm by observation or experimentation whether  $2+2$  really equals 4, or whether every point of a perfect circle is equidistant from the centre. Indeed, some of the core principles of many or most metaphysical systems have arguably been developed and accepted on the basis of *a priori* arguments. The empirical sciences had not advanced far enough to really contribute anything that could support or challenge the *a priori* arguments when the principles were first conceived. Examples of such principles are (i) the law of non-contradiction, (ii) that nothing comes into being out of nothing (an ancestor to the conservation law of energy), (iii) Leibniz’ law of identity, (iv) the principle of continuity, (v) the principle of locality, and (vi) the principle of ontological determinacy (more about (iv)-(vi) below).

However, I find it difficult to see that the few principles that could possibly count as *a priori* principles, are enough to construe a metaphysical theory of reality. For instance, it takes a little bit more to say something interesting about change and causation, than just to say that nothing comes into being out of nothing and everything is always completely determinate. Indeed, many of our problems connected to change have to do with understanding how change can be accommodated within a system that stays true to the principles. So, I am sympathetic to the claim that APM may be able to arrive at conclusions about a handful of basic axioms, and yet I doubt its ability to construe a complete metaphysical theory on its own.

One reason I remain sceptical of APM, is that I don’t see we have much reason to think that it can amount to anything more than an exploration of the limits of human cognition rather than the limits of reality. I don’t exclude that some of the results of an exploration of the limits of cognition may actually generalise to mind-independent reality, or that some features of cognition coincide with features of reality as a whole, but I also think we need to support any inferences from the fundamental features of human cognition to the features of mind-independent material reality, by appeal to an agreement with

the theories and findings of the empirical sciences regarding the nature of mind-independent reality.

Suppose, for instance, that rational *a priori* reflection brings us to the conclusion that we are unable to conceive of anything that would be in two contrary states at the same time and in the same location (or no specific state at all). Are we justified in inferring from the fact that we are unable to conceive of any such thing, that therefore mind-independent reality cannot be like that? It seems to me that we have reason to hesitate about any such inference, since we are at present still struggling to understand the connection between mind and body. Why should we infer that what holds for the mind also holds for the body, given our ignorance about the connection between mind and body?

In sum. Perhaps the conclusions we reach on the basis of *a priori* reflection do as a matter of fact hold also of material reality, but we have independent reasons to want the theories and findings of the empirical sciences to agree with these conclusions, *and* we should acknowledge that any inconsistency between them gives us reason to consider whether *a priori* conclusions must be abandoned or modified.

The upshot of my discussion so far is that while the above-mentioned principles may initially have been introduced and accepted on *a priori* grounds, sometimes millennia ago, it is arguably the fact that the empirical sciences have not contradicted them but instead continue to make use of them, that they remain a part of our basic presuppositions about what reality is like. In that case, they have *also* received continuous empirical support since they were first speculatively introduced on *a priori* grounds. However, it appears that we now may perhaps have some empirical findings and theories that seriously question them. Quantum indeterminacy, if real and not only epistemic, challenges the principle of ontological determinacy; entanglement, if not only correlation, threatens to challenge the principle of locality; and the discreteness found on the quantum level, if not only epistemic, threatens to challenge the principle of continuity. To my mind, the fact that we are even asking these questions tells me that even if some fundamental theses have de facto been introduced into the scientific/philosophical awareness by *a priori* arguments, the question of whether they ultimately are true may still be a largely empirical affair. One idea behind unification is that if the *a priori* reasons and arguments are in agreement with the empirical theories and findings, this serves the same justificatory role as triangulation in science; neither has ultimate priority, but when both point to the same conclusion, they mutually support each other.

One can wonder if modern physics, with its ever-increasing reliance on mathematical reasoning, is actually in an analogous situation to the one we find in metaphysics. That is, that we have a division between *a priori* and naturalist physics. *A priori* physics would be one where theoretical physicists explore—not the limits of conceptual space like APM—but the limits of mathematical space, and where it is sometimes assumed that the mathematics describes what is ultimately real, while the experimental side of physics only describes which possible version of the real is materially manifested in the dimension we inhabit. We can then understand the Everettian interpretation of quantum mechanics as saying that every possible version allowed by the mathematics is materially manifested, but each one is situated in a dimension of its own, which exists somehow parallel to ours and yet interacting in subtle ways (most notably ways that would explain what is currently unexplained by the standard model). This interpretation represents a break from the traditional view that empirical observations are the ultimate judge concerning which of the many mathematical solutions derived from the fundamental equations, actually describe reality and which ones don't. The mathematics itself seem to allow much more than is actually the case. Now, I only mention this analogy in order for the real experts to consider whether it has some merit, because I am not competent to do that. My focus is on metaphysics and not on physics, but I felt I should still mention the analogy as food for thought for others.

I believe the naïve view that APM captures the essence of all metaphysics, is an unfortunate side-effect of the age-old polarisation between empiricism and rationalism over the role of rational reflection in our attempts to find out what the world is really like. For some reason there has been a tendency to assume that the answer is either that rational reflection has no role to play whatsoever—empirical observation is the only way to know anything about the world—or that it is only through rational reflection—*independent of empirical observation*—that we find out anything of lasting value. On the latter view, i.e. according to APM, empirical observation only reveals how the world appears to be in

observation/measurement, but not what it is really like; only rational reflection can bring us the extra inch beyond the appearance to reveal reality, and this step must be taken without aid from observation.

Making a long story very short, the idea that metaphysics is bad for physics is based on the assumption that APM is the only metaphysics there is. Physicists are right to be sceptical about a unification between APM and physics, because APM really is a *philosophy-first-physics-later* kind of view. Luckily, there is another option, notably MetNat (see below).

It bears to note that some empirical scientists and empirically minded philosophers also agree that empirical observation does not reveal anything about reality. But since they also think rational reflection is equally impotent, they conclude that we cannot find out what things are really like. They take empirical science only to have the advantage of being able to find out how to reliably manipulate the world to fit our needs, but not to find out what the world is really like. I won't attempt to delve further into that position here, but for those interested see [8].

### 3. Metaphysical naturalism

Before I begin, let me point out that what I label 'metaphysical naturalism' (MetNat) is my personal take on how metaphysics and the empirical sciences can be conceived as pursuing the same goal with pretty much the same intellectual resources, and yet are distinct. It can be understood as a freely adapted fusion of what David Papineau calls 'ontological' and 'methodological' naturalism [9]. I won't claim it is the only kind of metaphysics there is, or that it is the only kind fit for unification. I defer to Papineau's expertise for the nuances and differences between various naturalist approaches and focus only on presenting one way in which metaphysics and physics can be seen as different and yet continuous with one another.

As already stated, MetNat doesn't deny the value of *a priori* reasoning, but it does not accept that its results are unconditionally generalisable to mind-independent physical reality prior to or independently of empirical knowledge. Rather, MetNat tries to unify the results of *a priori* reasoning with the theories and findings of the empirical sciences to produce a coherent worldview. However, MetNat is different from any particular empirical discipline, because it operates on a different level of generality; it really operates on a meta-level. Allowing myself a healthy dose of oversimplification, then the empirical sciences each focus on a specific domain of reality, in an attempt to understand the particular phenomena within that domain. Physics focuses on the elementary particles, their properties, and the particular interactions they engage in. Chemistry focuses on compound entities—constituted by the simpler entities studied by physics—and the reactions that occur between the compounds. Biology focuses on even more complicated systems and their behaviour. The demarcation between chemistry and biology might perhaps be drawn between systems that have some form of function or causal feedback loops that allow them to grow, reproduce, and evolve.

MetNat, on the other hand, focuses on broader categories of entities and more general aspects of the ways those entities interact; categories and ways of behaving that cut across the domains of reality that are the focal point of each empirical discipline. Physics deals with the very fundamental entities, say, electrons and their charges and how charged particles interact. It doesn't deal with cells, cell-division, or metabolism in mitochondria (although some aspects of physics may be relevant for our understanding of these phenomena), and it certainly does not consider whether there are classes of phenomena that we find in all the domains. That is what MetNat aims to do. It looks at all the different entities studied and described by the different sciences, and the manner in which they interact, and asks if there are any similarities in the characterisations of widely disparate phenomena. The result of such a scrutiny can be, for example, that every empirical discipline postulates entities that can be characterised as persistent bearers of properties (substances), the properties that they bear (properties), the relations they hold (relations), the interactions they engage in which bring about a change in them (causation), and more generally the changes that these bearers of properties undergo, or constellations of such bearers (events). Some changes may be uncaused, such as the change in the constellation of several causally unconnected objects in uniform motion.

It is not in the task-description of any of the empirical sciences to take a step back from their

individual discipline and to consider the most general characteristics of all the persistent entities in every domain, or of their properties, relations, events, causation, etc. The only discipline that tries to ask and answer such questions is MetNat. MetNat, as I construe it, is the business of asking whether all the descriptions of all the phenomena in all the domains fit into a general scheme that can be fruitfully applied in all the sciences, or even if they already have incorporated such a general scheme without realising it. General schemes of that kind are what I identify with metaphysical systems or metaphysical theories.

When I say that only MetNat develops general systems like the ones described above, I am not claiming that philosophy as an academic discipline has monopoly on doing MetNat. If an empirical scientist takes a step back and addresses questions of this kind, they have automatically shifted focus from their particular empirical discipline to do MetNat. Many enough have done precisely this, e.g. Galileo Galilei, Whewell, Duhem, Mach, Hertz, and Einstein, just to name a few. Indeed, isn't the Copenhagen interpretation of quantum mechanics only in degree separated from MetNat, in the sense of being a hypothesis about how to best understand the theories and findings of QM, but not as one that could really be decided in the laboratory? I mean, it wasn't established through measurement that entities have no determinate state before measurement. It is a conclusion of a rational argument that professes to show that this is the most reasonable conclusion we can reach on the basis of a multitude of empirical findings and the theoretical models at hand.

It is because MetNat operates on a higher level of generality that it becomes less immediately connected to the strictly empirical work, and more reliant on purely rational argumentation. We just can't bring a general category of, say, substance or causation, into the laboratory to test our hypothesis about it with the help of controlled experiments. Only particular substances can be brought into the lab and only the particular types of causal interactions that occur between them can be observed. Physics construes theories about the most fundamental components that go into the category of substance, on the basis of experimental output from the various sub-disciplines of physics. MetNat construes theories about reality as a whole, on the basis of the theories from the various empirical disciplines that each focus on a particular domain of reality. Even if MetNat isn't directly involved in the collection of empirical data, it acknowledges that its results must in the end conform to that data. And if new data becomes available through technological advances, to first change the theories of a particular empirical discipline, this should in the end come up on the table in MetNat perhaps calling for a re-evaluation of our overall world view.

In the approach I take in my research, the findings and theorising of the empirical sciences—at least those parts I can hope to understand—are taken into account as a valuable input on how the world really is, and as providing a plethora of explanations of how things work. I take them also to be an authority with regards to figuring out how things do not work, i.e. for excluding some explanations. I contrast that input with input about how we make sense of the world in our everyday conceptual scheme, and how we talk about them, as well as phenomenological analysis, and I pitch the findings from each of these approaches against the other in an attempt to find some way to bring it all together in one coherent whole. If one approach seems to say something very different from the other, we need to find an explanation as to why that is. Either it is because one is right and the other wrong, or vice versa; either way we need to figure out how one or the other can be wrong. In doing that, we will be construing some way that it all fits together. I take this to be pretty much the role of metaphysics as described by Johansson [10], Lowe [11], and Heil [12], although we might disagree on some details.

I don't believe we can come to any conclusion about the world merely by scrutinising language, or merely by phenomenological analysis, or merely by *a priori* reflection on the conceptual scheme already in place, or merely by accepting the facts and theories of physics, or chemistry, *etcetera*. Metaphysics, in the sense I have sketched it, is a project beyond the scope of an individual. We all take a shot at some part of the overall project, in our own limited way, and in time, over generations, we hopefully move towards greater clarity. Further on, I will illustrate how I have applied this approach to improve our understanding of causation, but first some words about the virtues of unification.

#### 4. The metaphysical basis of unification

As already stated, it is important to strive for unification of fields and theories—within and across disciplines—as a counterweight to the increasing fragmentation of science and philosophy. Now, I may be wrong about increasing fragmentation, but it doesn't hurt to formulate explicitly what good can come from unification. What, then, is unification and what are its methodological virtues? In their respective contributions to this volume, Styrman and Suntola stress the need to develop a common unified ontology that is empirically sufficient, metaphysically minimal, and generally constitutes a virtuous belief system for human beings. The principle of economy or unifying power is to be used to decide between alternatives that have the same predictive and explanatory force but are mutually incompatible. Their hypothesis is that an ontology of that kind can provide resolutions to long-standing problems that cannot be resolved only within an isolated topic. I agree to all that but I want to draw attention to a couple of metaphysical principles that are not so much ontological, i.e. they don't say what kind of entities are real, but are even more general and which can highlight some of the reasons we can have for thinking that a unificationist approach could succeed where more specialized approaches fail.

First, a unificationist approach is appropriate *if* we are right to suppose that the reality where we live in surely must make up a *determinate* and *unified* whole; ergo, we should expect our understanding of that whole to also make up a unified whole (please note; disambiguation of 'determinate' follows below, to avoid identification with 'determinism'). On that assumption, fragmentation and disunity are signs of an inadequate understanding of the world as a whole. If we assume to the contrary that reality is fragmented and indeterminate, it seems to follow not only that our knowledge should be equally fragmented and indeterminate, but also that we stand little chance of ever being able to understand it; the world should strike us as being non-uniform and largely unintelligible. Accordingly, the assumption about a determinate and unified reality is really an assumption about the preconditions for the intelligibility of the human endeavour to understand reality. To assume the opposite is to assume that our effort is doomed to failure, at least if our effort is to understand reality as a whole.

It is possible to think that reality is split into distinct domains between which there is no intelligible connection, say, between the mental and the physical, and that we therefore we must understand each domain individually. This is called dualism. But we can then also say that unless each separate domain makes up a determinate and unified whole, we can have no hope to understand them individually either. Unless the physical world makes up a determinate and unified whole, we cannot hope to fully understand it; we can only fully understand each part individually.

The idea that reality must be a determinate and unified whole in order to be rationally understood is found in many philosophical traditions, both implicitly and explicitly, e.g. in Aristotelianism, Stoicism [13] and Idealism [14-15]. This idea was very prominent in Leibniz' philosophy, embedded in the principle of sufficient reason [16], which combines the idea of the world being a unified whole with it being rationally intelligible. The fact that so many different traditions embrace the same idea, despite deep disagreements about the nature of the world, and that it has remained so long as a basic assumption in our intellectual endeavours, supports its status as a presupposition many find unavoidable to motivate the effort we make to understand the world.

It is important to note that we are really talking about a combination of three interrelated fundamental beliefs. First, we have what is called the *principle of ontological determinacy*: the idea that reality is always perfectly determinate [2]. To say that reality is 'determinate' is not equivalent to saying it is 'deterministic', although it being determinate is a precondition for it being deterministic. The principle of ontological determinacy primarily states that every entity in the universe, and hence the universe as a whole, must at any given time have a determinate nature; it forbids the possibility that anything is in two incompatible states at the same time and place, and/or does not have any determinate nature. Determinism, on the other hand, states that any such determinate state of the universe is by necessity determined by its previous states and necessarily determines its later states. Determinism reasonably presupposes determinacy, but to get from determinacy to determinism it is not enough that everything has a determinate nature. One must also add that this nature entails causal determinacy, and this is a disputed point. The dominant philosophical views of causation, so-called Humean views, admit that

everything always has a determinate nature, but deny that this nature causally necessitates future states. The connection between the principle of ontological determinacy and determinism is complicated, but it is one we need not sort out here.

McTaggart thought that the principle of ontological determinacy is so fundamental that he called it the *Total Ultimate Presupposition*. It is a presupposition because it cannot once and for all be proved since it is about absolutely everything, whether future, present, and past, and whether or not it is known to humans. It is fundamental because it is the basis for our conviction that the world can be made sense of at all. Assume that the world is indeterminate, i.e. either is in incompatible states or no state at all, and it follows that it cannot be known, from which it follows that science is ultimately futile. Could we at least know that reality is indeterminate? I am not sure what to make of that thought. Partly because in knowing that the world is indeterminate we would not know what it is like; we would just know that it both is and is not a certain way, and/or that it does not have any particular nature. Furthermore, it seems that we could only know that some specific domain of reality was indeterminate, by its failure to act in a determinate way on measuring apparatus that we can assume to be determinate. If we cannot make that assumption about the measuring equipment, then how are we to tell whether the indeterminacy comes from the state of the system we measure, the state of the system we use to measure, or both? Anyway, Andrew Newman has argued that physics always makes use of this principle [2], and that as for explaining the success of physics, there is no alternative; there just doesn't exist any metaphysical theory to go along with physics, of which the principle of ontological determinacy isn't a fundamental axiom [2]. Indeed, it is arguably the appearance of a particular domain—the domain of quantum phenomena—as being anomalous with respect to the principle that is causing us trouble. I am not saying it is inviolable, but pointing out that a rejection of the principle does threaten the very intelligibility of science, in the absence of something that could replace it.

Second, we have the *principle of continuity*, which I will describe here as the idea that nature never makes leaps, that every natural change is produced by degrees [17]. Leibniz made use of this law in justifying infinitesimal calculus, but then in the following paraphrased form: “in any supposed continuous transition, ending in any terminus, it is permissible to institute a general reasoning, in which the final terminus may also be included” [18]. This is sometimes whittled down to ‘whatever succeeds for the finite, also succeeds for the infinite’ [19]. The point is that an understanding of nature as continuous motivated the understanding of mathematics as continuous. Leibniz also made use of this principle to criticize Cartesian mechanics. Descartes assumed objects could be in a state of absolute rest, and then change their state of motion from rest to motion. Leibniz believed this to be impossible, because the change from absolute rest to motion—however tiny that motion was—was a leap from no motion to motion which couldn't be continuous. On the back of that reasoning Leibniz argued that all objects must in reality always be in a state of motion and hence there was no state of absolute rest. Today it is a basic postulate of relativistic physics that we only can talk about a state of rest relative to a frame of reference.

The principle of continuity isn't really confined to the continuity of different kind of changes, but also applies to the interconnectedness of everything. If one characteristic has no connection whatsoever to some other particular characteristic, that amounts to a discontinuity between the two. Of course, the two need not be immediately connected, but at least connected through intermediaries. Two things that neither can causally interact directly, nor via intermediaries, are arguably not parts of the same universe. It is not difficult to see how the principle is connected in the same way to the principle of locality; a cause can only exert its influence on something either directly or via a continuous chain of intermediaries.

Now, these principles may have been adopted for *a priori* reasons, but it seems reasonable to suppose they have survived since ancient times because they also appeared to gain support from the theories and findings of the natural sciences. It is only with the advent of relativistic and quantum physics that doubts have been raised about the validity of some of them. As a metaphysical naturalist I am committed to accept that these new findings could ultimately compel us to abandon or modify these principles, but I'd like us to be well aware of the cost when/if we do.

If we accept the principles of ontological determinacy and continuity, we can make the case that the unificationist approach is methodologically virtuous in much the same way methodological

triangulation is virtuous, *if* the world makes up a determinate and unified whole. We can suspect that each particular method of measurement is to some degree fallible, and so we seek to validate it by comparison to other methods. If different methods come to same conclusion, they support each other. Similarly, if our understanding of one part of reality—a reality ultimately assumed to make up a unified and determinate whole—fits with our understanding of other parts, this can be taken as mutual support for the validity of our understanding of each different part. Basically, if the world is a-determinate and unified whole, unification offers a methodology that takes advantage of that fact.

From the perspective of the natural sciences, the principles of ontological determinacy and continuity go a long way to motivate the intelligibility of science. However, my aim was to disseminate the basic ideas involved in the belief that ‘reality must be a determinate and unified whole in order to be rationally understood’. The first two principles address the ‘determinate’ and ‘unified’ aspect of the world, which also serve as the natural preconditions for a rational *understanding*; ‘understanding’ has to do with the relation between world and mind. So, I think there is room to add a third ‘principle’ into the mix, which is that any understanding of the world is incomplete without an understanding of the generation of experience and rational thought. It might not be widely known as a principle, although one could make the case that it is at least implicitly found in Leibniz, and later explicitly in McTaggart (I rely on the latter). Indeed, I think it is implicit in Suntola and Styrman’s claim unification strives for a virtuous belief system *for human beings* (or beings able to construe representations of the world).

The virtuous belief system we ultimately should want is one that takes into consideration the mind and its contents as a phenomenon that needs to be explained, as well as its connection to the physical. In trying to understand the world we must try to understand the mind and its place in nature too. We should ultimately be trying to answer the question: what is the world like such that it can contain minds whose thoughts and words relate to subject matters distinct from those thoughts and words? In fact, it has been plausibly argued that subjective experience may contain an important criterion of success for any objective theory about the world, even if it is agreed that subjective experience provides poor evidence for what the world is really like [15].

The general idea is that any theory about what things are really like can be tested by asking whether it offers a conceptual model of reality that explains why things actually appear to us in the way that they do. The model need not resemble the appearance, but if it differs from the appearance it must explain what it is about the world that allows it to appear so different from what it really is. As long as the model cannot explain the characteristics of experience, the facts of experience constitute an anomaly for the theory. If we have a model that claims the world is different from experience, and yet is able to explain how it can appear in the way that it does, the appearance becomes a *phenomenon bene fundatum*; a well-founded datum of experience.

Consider for instance the way quantum electrodynamics (QED) explains the physical basis of how objects reflect light [20], and which in turn becomes an important component in explaining colour perception. QED tells us that objects are really quite different from what they appear to be like in perception. However, the model it offers of the physical constitution and working of objects along with the trichromatic theory of colour perception (a biochemical theory) does offer a plausible account of why objects appear to us the way that they do. That is a part of why there is no great controversy about QED; it can be fitted into a more general model that explains why the world appears to us in a way that doesn’t self-evidently match the physical reality. This doesn’t mean that there are no philosophical controversies about colour perception, only that these controversies don’t challenge the truth of QED.

In contrast, there is quite a lot of controversy regarding the compatibility of what physics is supposed to be saying about the nature of time, with the way time appears to us in perception. This can be taken to indicate that we still don’t understand fully the physical basis of time; time is not yet a *phenomenon bene fundatum*.

## 5. Causation as Case Study

Here I will attempt to give a rough idea of how MetNat works ‘in action’, taking as an example the nature of causation. Causation is primarily a subject matter for metaphysics rather than any empirical

discipline, despite being a concrete physical phenomenon. This is because it is a *type* of phenomenon—popularly believed to be responsible for much of what is going on in the world—whose instances are found across the various domains of the individual empirical disciplines: everything from planetary motions to interactions between elementary particles, reactions between chemical compounds, bacterial infections, a corner kick on the soccer field, and pounding the keyboard trying to write something intelligible. To give an account of causation is to offer a general model that explains what all these various particular instances have in common. All the disciplines offer their input, but to make a call on the general level, one has to take a step back from the particular disciplines and consider the matter from a meta-perspective.

To my mind, causal realists up until the 18<sup>th</sup> century, regardless of whether they aligned with the Aristotelian or mechanistic tradition, took a MetNat approach. As I have outlined elsewhere in greater detail [21-23], then from antiquity and well into the early modern period—roughly from Aristotle 350 BC to Hobbes AD 1656—one can identify a view of causation about which the Aristotelian and mechanistic philosophers agreed, despite various disagreements about detail. Roughly, it was agreed that causation is the production of change through interaction of powerful particulars, i.e. that whenever an object of a certain kind, interacts with another object of a certain kind, the interaction always brings about a certain kind of outcome; whenever a brick with a certain momentum collides with a window with a certain kind of microstructure, the window will break.

To be sure, philosophers from the different schools of thought *disagreed* about the physical properties that objects actually had, whether objects were properly conceived of as unities of form and matter (Aristotelian) or just collections of tiny solids (mechanistic), and finally, whether there was a purpose in nature independently of human or divine agency. That disagreement notwithstanding, it was agreed that it was possible to acquire knowledge of the physical properties of objects, that these properties determined their behavior—i.e. that natural properties were *powers*—and that therefore our knowledge of powers allowed us to deduce how the objects would behave in various types of interactions. In contemporary terms, knowledge of the relevant fundamental properties of electrons (i.e. the quantities momentum, spin, and charge), allows us to predict the range of behavior exhibited by interacting electrons, given knowledge of different initial values of the quantities possessed by the electrons.

The powerful particulars view accepted from antiquity to early modernity—let me call it the *old* powerful particulars view—rests on the foundation of three basic principles about the nature of material reality, which are still widely assumed to hold true. First, the materialist principle that nothing comes into being out of nothing and nothing is ever completely annihilated, sometimes called the *principle of the perpetuity of substance* [3] and sometimes the *genetic principle* [1], which can be seen as an ancestor to the conservation law of energy. The term ‘genetic principle’ highlights that the principle is really an embodiment of the conviction that everything has a natural origin; there is no magic. Second, the conviction that everything always has a determinate nature *and* that this nature determines how these objects change when they interact with one another. This principle is now either called the *principle of the uniformity of nature* [3], or the *principle of lawfulness* [1]. The core idea is that as long as the nature of things remains the same, they shall behave in the same way; salt, wherever we find it in the universe, will always dissolve in unsalted water at 20°C. Third, the conviction that nothing ever happens unless provoked by a compulsion, which is the original meaning of what we now know by the name the *causal principle* [1], and widely known in terms of the slogan ‘there is a cause to everything’.

Two comments are in place about these fundamental principles. First, the causal principle was formulated before the law of inertia was discovered, i.e. that objects continue in their state of motion in the absence of intervening forces. This can be taken to suggest that some changes are non-causal, say the constellation of three arbitrary objects moving uniformly and independently of each other. Uniform motion obeys the genetic principle (everything has a natural origin) and the principle of the uniformity of nature, but the resulting change in position is not causal. Ergo, there actually isn’t a cause to every change. It is partly because of this consideration that the phrase ‘there is a cause to everything’ is usually understood today as meaning ‘there is a natural explanation for everything’. To explain causation is

therefore only to explain the class of causal changes, and, naturally, to explain what it is that distinguishes causal changes from non-causal changes. In the causal realist tradition, the distinction is between changes that occur spontaneously (non-causal), and those that occur as the result of the exertion of influence.

Second, that our acceptance of the three principles as regulative ideas governing the nature of causation, either individually or together, cannot reasonably be based on *a priori* reasoning. This is because they are *conceptually* speaking independent of each other, and independent of the idea of coming into being. We can conceive of a world where everything comes into being out of something else in accordance to the genetic principle, and yet in a spontaneous and haphazard way in violation of the causal principle and uniformity. We can also conceive of a world where everything comes into being *ex nihilo* by the power of a deity, and therefore in violation both of the genetic and causal principle, while still being lawful, in a sense, *if* the deity only wills in accordance to the principle of sufficient reason. It is even possible to think of substance coming into existence for no reason at all, i.e. not out of anything else, not in accordance with any general law, and not because of any kind of influence, not even divine will; it is possible to think of becoming as violating all three basic principles. Consequently, the idea that in the actual world nothing comes into being spontaneously out of nothing, but always out of something else in a lawful manner, and usually as a result of some kind of action, does not derive its appeal from any conceptual *a priori* necessity binding the three principles together, nor them with becoming. Their appeal is based on being continuously confirmed by observation of the world, and/or on its success in explaining what we observe. Also, I believe, because we realize that to accept the reality of violations of these principles threatens to undermine the very purpose of science; their reality will mean the world is to some extent beyond our abilities to understand it. Nevertheless, if we come across any phenomenon that appears to violate the principles and we are unable to explain away the inconsistency, we have empirical reason to doubt the validity of the principles. Indeed, we may already have come across such phenomena—quantum indeterminacy, entanglement, and discreteness—but the jury is still out on whether they are genuine anomalies for the three principles. If we ultimately decide they are genuine anomalies, then this would be to take a MetNat approach to metaphysics and physics and reject *a priori* metaphysics.

Let us now turn back to the illustration of the application of MetNat to the issue of causation, working on the assumption (for the sake of argument) that the three principles still hold. Based on those premises, the old powerful particulars view is in many ways in good agreement with the way material changes are described by the natural sciences today. Consider Coulomb's law (the vector form), which describes the behavior of charged particles when they interact. We have here an equation that allows us to calculate the 'continual mutation' in the state of motion of particles as they mutually exert a force on each other over a period of time. This allows us to predict the sequence of states over time that the system of particles goes through, and it is assumed that this sequence is produced by the influence exerted between the particles.

It should be acknowledged that the old powerful particulars view is not typical for mainstream views about causation in philosophy. The views that *The Oxford Handbook of Causation* [24] lists as 'standard approaches' to causation in contemporary philosophy, are views that come out from the empiricist tradition and they offer a very different take. None of them give any explanatory role to powers, and/or the exertion of influence between the particulars that bear the powers. Causation, according to these approaches, is a relation that holds between 'events'. The term 'event' is a technical term that is understood as a qualitative state of anything at a given time (an object or system). Accordingly, the *regularity approach* takes causation to be understood as an invariant and unique succession of events or states. It says that the event *C* is the cause to the event *E*, if and only if (*iff*) whenever *C* occurs, then *E* always follows. The *conditional approach* is basically a further refinement saying that the regularity isn't dyadic but triadic, notably whenever *C* occurs in the circumstances *S*, then *E* always follows. The *counterfactual approach* says that *C* is the cause to *E* *iff* *E* does not happen unless *C* happens, and finally, the interventionist approach says that *C* is the cause to *E* *iff* *E* comes and goes away when you manipulate *C*.

In common with all these approaches is the empiricist assumption that we shouldn't speculate about any intrinsic nature of  $C$  such that this nature explains why  $C$  brings about  $E$ . Instead, we infer that some phenomenon  $C$  is the cause to  $E$ , because we discover empirically that a regularity/conditional regularity/counterfactual dependence/manipulation dependence obtains between the two. Most importantly for my purposes here is that causation on these accounts is a successor relation between qualitative states that isn't explained by the nature of the objects that constitute the qualitative states.

If one tries to apply the standard approaches to Coulomb's law, then they confine us to define cause and effect in terms of the succession of two states  $\varphi$  and  $\psi$ , specified as the position and sum of the relevant quantities of the two particles at two successive times  $t_1$  and  $t_2$ . Consequently,  $\varphi$  is the cause to  $\psi$  iff whenever states of type  $\Phi$  occur they are always followed by states of type  $\Psi$ , or iff  $\Psi$  only occurs when  $\Phi$ , etc. The point is that on the standard accounts we are not meant to understand Coulomb's law, or any theory underlying our understanding of what the law says, as really doing anything other than describing the succession of states given initial conditions, but not as explaining what makes that succession come about. In other words, we are supposed to understand Coulomb's law in the same way as Fourier's heat equation; as an equation that describes *how* heat flows but doesn't say *what* heat is or *why* it flows in the manner described by the equation.

There is no space here to delve into the complications involved in justifying any conclusion about whether physics and/or philosophy really can or should explain rather than just describe the changes that the world undergoes. The point here is to illustrate what a choice in favour of MetNat and explanation can entail. One advantage seems to be that it offers an account of causation that stays close to the explanatory power of the theories and findings of the natural sciences. If an explanatory view of physics is appealing to the reader, MetNat should be appealing too. We can, I hope, apply Styrman's principle of economy and unifying power to support this approach.

One challenge facing MetNat now, is that while the old powerful particulars view is in some ways better in agreement with a reading of many fundamental physical laws—provided we'd like to understand them as explanations rather than mere descriptions—then other aspects of that view were arguably falsified already with the birth of Newtonian physics. In particular, the old powerful particulars view characterises physical interactions as *unidirectional*; one thing influences another, which in turn receives the influence and suffers a change. Today the natural sciences take for granted that unidirectional actions simply do not occur. What may superficially look like a unidirectional account turns out to be reciprocal action under the microscope of science. Aristotle described the unidirectionality in the following way: “whenever the potential active and potentially affected items are associated in conditions propitious to the potentiality, the former must necessarily act and the latter must of necessity be affected” [25]. Hobbes, in a similar vein, states that a body “is said to work upon or act, that is to say, do something to another body, when it either generates or destroys some accident in it” [26]. The falsity, or inadequacy, of these statements should have gradually dawned on philosophers and physicists alike, when Newtonian mechanics became accepted as the new paradigm of natural science. This is a science that accepts the third law of motion as a universally valid statement about any interaction, roughly as tantamount to saying that whenever any object whatsoever exerts an influence on any other object whatsoever, the latter simultaneously acts on the first in the same way and to the same magnitude. If the interacting objects change in different ways due to the same kind of influence, that is down to the difference in the qualitative state of each thing as they entered the interaction; a window acted upon with a certain force  $F$  will break, while a brick acted upon by an oppositely directed force  $-F$  of the same kind and magnitude, will merely change its state of motion.

As far as I am aware, it wasn't until 1959 that the philosopher Mario Bunge clearly pointed out the problem [1], but he still argued in favour of a view of causation very similar to the old powerful particulars view. And then it took until 2002 before I picked up on Bunge's ideas and attempted to sketch an account of causation that took seriously the reciprocity of interactions, as described by the natural sciences [21], and attempted to modify the old powerful particulars view. My suggestion in that paper, in extreme paraphrase, is that we must abandon the old view that a cause is the influence exerted by one thing on another, and an effect is the change affected in the object acted upon. In its place we

should acknowledge that every instance of causal change is the result of a reciprocal action between powerful particulars, and therefore that the concept of cause should be identified with ‘interaction’ as this is defined by science. We should always treat the interaction of brick and window as the cause to the changes that both brick and window undergo until, finally, we have a brick lying at rest in a pile of broken glass. Any description that merely looks at what the brick does to the window, ignores what the window does to the brick.

My suggestion seems to have considerable potential as a general account of causation in the various domains investigated by the different empirical disciplines, although the empirical work necessary to substantiate such a claim is yet to be carried out in most disciplines. In physics, all interactions are already described in this way, and chemical reactions are at least implicitly recognized as being reciprocal in the same way. In biology we face more uncertainty. It is true that many biological processes seem to be a continuous series of reciprocal interactions between entities, such as the various stages of the transportation of oxygen from the lungs to the mitochondria, and the citric acid cycle. However, more complicated biological processes, in particular those that involve causal feedback loops are more difficult to gauge. I won’t venture to make any firm claims about that at this stage. Finally, we do have a problem with intentional agency, such as the ones we ourselves carry out. The problem is that we seem able to initiate actions on the basis of our ideas about outcomes we wish to bring about, but which do not yet exist. How such ideas are to be understood as entities engaging in interaction with the physical structures that bring those outcomes about, is still as much a mystery as mind-body interaction.

## 6. Concluding remarks

I have argued that while *a priori* metaphysics is not without merits, it cannot reasonably be considered self-sufficient with respect to providing an account of the ultimate structure of reality. Similarly, while each empirical discipline expertly explores a particular domain of physical reality, none of them individually can reasonably be said to answer questions about the whole of reality. Metaphysical naturalism, on the other hand, is an approach that attempts to merge the results of *a priori* reasoning with the theories and findings of all the empirical disciplines, in order to construe a unified world view. As such the output of metaphysical naturalism is best thought of as being motivated by a kind of inference to the best explanation. I believe such inferences are commonplace within every empirical discipline, but there the distance between the explanation so inferred and the empirical data from which it is inferred is smaller. The explanations that MetNat takes to be warranted by inference to the best explanation, are inferred from the general accounts taken to be warranted by inference to the best explanation from the empirical data. As such the general accounts that MetNat produces are further removed from the empirical data, but they are still falsifiable in so far as the theories are falsifiable from which they are generalizations. Accordingly, although physics and metaphysics are different, they are still not discrete enterprises; both are part of our joint effort to understand the world we live in.

I have also argued that in the common presuppositional depth-structure on which most of not all sciences rest, including metaphysics, we find a core of basic principles, or assumptions, whose explicit acceptance seem to commit us to thinking that unification, or the strive to unification, is important. If we assume that the world must ultimately make up a unified whole, in accordance to the principle of ontological determinacy and the continuity principle, then successful unification is a sign (albeit a fallible one) of the success of the explanations that apply to each domain. Why should we accept the basic assumptions? Because to deny them is to commit to the view that the universe is fragmented and discontinuous and thus ultimately cannot be intellectually understood. Does this mean they are somehow unfounded because unverifiable? Well, it is already widely accepted that scientific knowledge is in principle fallible, i.e. cannot be ultimately verified. I have pointed out ways in which the metaphysical principles can be falsified, and that should be enough to grant them status as knowledge only different in degree from the theories and findings of the empirical sciences.

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### Commentary

#### *Reviewer A. Comment 1.*

Quote from the text: “Uniform motion obeys the genetic principle (everything has a natural origin) and the principle of the uniformity of nature, but the resulting change in position is not causal. Ergo, there actually isn’t a cause to every change.” The object’s previous state and forces acting upon it caused the change in position. Why is this not a causal change?

#### *Reply.*

Let me point out first that the points I am making in this paper about unification or metaphysical naturalism, do not in any way hinge on the question of whether uniform motion is non-causal. Nevertheless, it is a very interesting question which I think should be answered separately, and at length, because it relates to an interesting problem about the distinction between *proximal* and *distal* causes. A discussion of that problem should be of interest for the readers, and also further illustrate metaphysical naturalism.

First, uniform motion has been understood for a very long time as a non-causal phenomenon. Indeed, the discovery that it is non-causal is often used as a way to contrast modern physics from outmoded Aristotelian physics, which assumed that every object had to be pushed locally from every position to any adjacent position. According to the modern view objects naturally continue in their state of motion without having to spend any energy in doing this. Admittedly, it is questionable whether any object ever is unaffected by forces, and so whether genuine uniform motion exists, but the main point is that even if every object is always being acted upon by forces, then in the case of non-accelerating bodies these forces are at least not pushing it in the direction of motion.

It is correct that the state of motion of every uniformly moving body was at some point caused by an interaction between the object and some other object. That interaction would count as the proximal cause to a certain change in the object’s state of motion, but it cannot be considered the proximal cause to all subsequent changes of *position* without violating the principle of locality; it is to conceive of an interaction occurring at one spatiotemporal location as the proximal cause of something occurring at a spatiotemporally distant location.

The standard response is that while the initial interaction is not the proximal cause of every subsequent change in position until the next interaction it is the *distal* cause, sometimes called the *ultimate* or ‘real’ cause; one whose influence is somehow particularly crucial for some change we are trying to explain, even though that influence is then mediated somehow to that particular change. The problem here is that the concept of a distal cause, as it is usually explained, is arguably an anthropocentric concept. The proximal cause to the sinking of the Titanic was that an iceberg ruptured the hull beneath the waterline thus causing a leak. The distal (or ‘real’) cause is that the captain decided not to slow down despite reports of icebergs because he thought the ship was unsinkable. Similarly, when a stray baseball hits a window and breaks it, the proximal cause is the force exerted by the ball on the window, but the distal cause is the manner in which the batter hit the ball such that it headed in the direction of the window. The batter will be the one to pay for repairs, because she was the one that hit the ball in that particular manner.

A less obviously anthropocentric example is the idea that while the perception of twinkling stars in the sky is proximally caused by photons stimulating receptors in the retina, the ‘real’ cause is the

emission of those photons from a distant star. The latter is anthropocentric because we are attempting to explain why *we* have an experience of a twinkling star even though the star does not proximally stimulate the retina. To be more precise, the explanation is anthropocentric because the criterion for singling out one particular phenomenon in the causal chain of interactions as the ‘real’ cause, is that it matches something particularly salient in our perception of the world; we are looking to explain what is the *reference* of the objects of perception, and whatever is believed to be that reference is declared the real cause.

We make a similar anthropocentric selection when we decide to interpret an interaction between brick and window in terms of ‘the brick broke the window’ rather than ‘the window caused the brick to change its velocity, momentum, and kinetic energy’ even when we know that we really have an reciprocal action between a brick and a window whose end result is a brick lying on the ground in a pile of broken glass. We simply don’t care too much what happens to bricks, but windows are expensive, a bother to substitute, and we get a nasty draft when they are broken. However, if we were sitting beneath the window and get a brick in the head, suddenly what the window did to the brick becomes more salient in our attempt to explain why we got hurt.

It seems to me that the only general account of ‘distal causes’ is that it is an anthropocentrically useful approximation in light of our explanatory interests, and that acceptance of a notion of ‘distal cause’ as anything more than that, only leads to a greater confusion about causation generally. As already mentioned, to say that a star is the distal or real cause to our perception of it twinkling, is to question the validity of the principle of locality; we are accepting that sometimes the real cause acts at a distance. If it is objected and said that the principle of locality is not violated because the influence must still be mediated by a chain of proximal causes  $P_1, P_2, P_3, \dots$ , then we are saying that distal causes are less fundamental than proximal causes, and we now have to explain why some particular interactions in the infinite chain of proximal causes, at the same time constitute a special class of causes that later become the ‘real’ causes to spatially and temporally discrete events. As far as I know, no other criteria exist other than what does and what doesn’t strike us as being particularly salient in our experience or conceptualization of the world.

Now, I am happy to just call this a problem with the distinction between proximal and distal causes, and not a proof of its unintelligibility. But it is my reason for thinking that we need to think of causation as being at rock bottom proximal, and that distal causation is at least secondary of proximal causation. In that light, I could settle for saying that uniform motion is at least non-causal in the proximal sense, and that a theory of causation needs first to focus on getting proximal causation right, because on all accounts it is the more fundamental one.

#### *Reviewer A. Comment 2.*

I gather that metaphysical naturalism is a matter of complementing a theory of physics with an ontological interpretation. Is it the duty of a metaphysical naturalist to criticize theories of physics, or only to humbly accept them and proceed with their ontological interpretation? For instance, it seems that there is no end to the process of interpreting ontologically the conception of time of the theory of relativity. What should a metaphysical naturalist do? Jump on board and carry on with the interpretation, or ask if there is something fundamentally wrong in the theory that they have interpreted for the past 100 years or so?

#### *Reply.*

My position is that it is not only within the power of metaphysics to offer ontological interpretations of the theories of physics—although I gather most metaphysicians limit themselves to do just that—but also to criticize them. However, the degree to which individual metaphysical naturalists can do this will depend on their knowledge of the physics, and their critique will probably end up being pretty close to being just physics; the difference is after all a question of degree. Now, even if a metaphysician is not qualified to engage in direct criticism herself, she can contribute to such a criticism by pointing out incompatibilities between the general theories of the different disciplines and thereby suggest to the

experts within each discipline that they should carefully think about this again. Without such arguments, the experts in each discipline might never come to think there was a problem.

*Reviewer A. Comment 3.*

The law of non-contradiction and absolute simultaneity have been deduced by a priori reasoning. If a theory of physics violates one or both of them, what should a metaphysical naturalist conclude? That they are bad rules and that nature is in fact contradictory and that absolute simultaneity is violated? Or that the theory which violates them is bad, i.e., that it had to assume something strange in order to explain phenomena? Does latter option indicate that a priori metaphysics after all has something to offer?

*Reply.*

At the moment I am not ready to admit anything more than that if a theory of physics violates a priori principles, this gives us reason to consider either that the a priori principles could be wrong or that the physics is wrong. I just don't have any clear idea about how to ultimately decide which of them is wrong/right. Or, rather, I don't know how that question could be settled either in an a priori way only, or only in physical terms. Perhaps a unified approach is more viable. Suppose we figure out that to change the principles in accordance to the anomalous physical theory, works across all domains, i.e. it doesn't lead to any puzzles regarding our understanding of other disciplines (and therefore of the whole). If that is the case, I think this would support the idea that there is something wrong with the a priori idea. But this is not to concede to physics any explanatory priority, because we decided for or against the change on a metalevel, even if the crucial input came from physics.

**References**

- [1] Bunge M 1959 *Causality* (Cambridge, MASS: Harvard University Press)
- [2] Newman A 1992 *The Physical Basis of Predication* (Cambridge: Cambridge University Press)
- [3] Dilworth C 1996 *The Metaphysics of Science* (Dordrecht: Kluwer Academic Publishers)
- [4] Carnap R 1928 *The Logical Structure of the World & Pseudoproblems in Philosophy* (Peru, IL: Open Court) rpt. 2003
- [5] Neurath O 1959 Protocol sentences, ed A Ayer *Logical Positivism* (New York: Free Press)
- [6] Weinberg S 1994 *Dreams of a Final Theory* (New York: Vintage Books)
- [7] Hawking S 2012 *The Grand Design* (New York: Bantam Books)
- [8] Torretti R 1999 *The Philosophy of Physics* (Cambridge: Cambridge University Press)
- [9] Papineau D 2016 Naturalism, ed E Zalta *The Stanford Encyclopedia of Philosophy*  
<https://plato.stanford.edu/archives/win2016/entries/naturalism/>
- [10] Johansson I 1989 *Ontological Investigations: an Inquiry into the Categories of Nature, Man and Society* (London: Routledge)
- [11] Lowe E 1998 *The Possibility of Metaphysics* (Oxford: Clarendon Press)
- [12] Heil J 2003 *From an Ontological Point of View* (Oxford: Clarendon Press)
- [13] Baltzly D 2019 Stoicism, ed E Zalta *The Stanford Encyclopedia of Philosophy*  
<https://plato.stanford.edu/archives/spr2019/entries/stoicism>
- [14] Hegel G 1873 *Hegel's Logic*, trans. W. Wallace (Oxford: Clarendon Press) rpt 1975
- [15] McTaggart J 1921/1927 *The Nature of Existence*, Vols 1 and 2 (Cambridge: Cambridge University Press)
- [16] Melamed Y, Lin M 2018 Principle of Sufficient Reason, ed E Zalta *The Stanford Encyclopedia of Philosophy*  
<https://plato.stanford.edu/archives/spr2018/entries/sufficient-reason/>
- [17] Jorgensen L 2009 The Principle of Continuity and Leibniz's Theory of Consciousness *Journal of the History of Philosophy* **47** 223–48
- [18] Leibniz G 1710 *Theodicy: Essays on the Goodness of God, the Freedom of Man, and the Origin of Evil*, trans. E Huggard (LaSalle, IL: Open Court) 1985.
- [19] Katz K and Katz M 2012 A Burgessian Critique of Nominalistic Tendencies in Contemporary Mathematics and its Historiography *Foundations of Science* **17** 51–89.
- [20] Feynman R 1985 *QED: The Strange Theory of Light and Matter* (New Jersey: Princeton University Press)
- [21] Ingthorsson R 2002 Causal Production as Interaction *Metaphysica* **3** 87–119
- [22] Ingthorsson R 2007 Is There a Problem of Action at a Temporal Distance? *SATS–Northern European Journal of Philosophy* **8** 138–54.
- [23] Ingthorsson R 2019 Mario Bunge and the Current Revival of Causal Realism, ed M Matthews *Mario Bunge: Centenary Festschrift* (Springer Verlag) pp 205–17.
- [24] Beebe H, Hitchcock C, Menzies P 2009 *The Oxford Handbook of Causation* (Oxford: Oxford University Press)
- [25] Aristotle 1935 *Metaphysics*, ed H Tredennick *Aristotle*, vol. XVIII (Cambridge MASS: University Press).

- [26] Hobbes T 1656 *Elements of Philosophy Concerning Body*, ed W Molesworth *The English Works of Thomas Hobbes of Malmesbury* (London: Bohn) rpt 1839.
- [27] Espinoza F 2005 An analysis of the historical development of ideas about motion and its implications for teaching *Physics Education* **40.2** 141