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Quiet Causation and its Many Uses in Science

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Abstract: This chapter defends a deflationary, or 'quietist' account of causation in science. It begins by laying out the elements of four central philosophical theories of causation, namely the regularity, counterfactual, probabilistic and process accounts. It then proceeds to briefly criticise them. While the criticisms are essentially renditions of arguments that are well-known in the literature, the conclusion that is derived from these is new. It is argued that the limitations of each of the theories point to a deflationary or quietist approach to causation in science. The practical focus is on interventionist methods for causal inference in physics and biology, and on the extant debates within the philosophy of each discipline as to how best to approach such methods. It is then argued that none of the four central theories proposed can completely explain or reduce the methods of causal inference that appear in each science. Yet, each theory provides partial insights into some of the grounds of causal inference and causal discovery. It is consequently suggested that we should retain the various methodological lessons without committing expressly to any metaphysics of causation.

1. Philosophical Theories of Causation

There is a very long history by now of philosophical attempts to understand causation, and consequently a long list of philosophical accounts or theories of causation are available. (See Illari and Russo's Introduction and Maziarz's Chapter 2 in this volume). Inevitably there is therefore now some degree of judgement in selecting out a few for special treatment. However, I think it is widely accepted that the most significant proposals can be divided into four different types, which roughly subsume them all – sometimes in combination, since some proposals are hybrids of some of these approaches. [1] And, although I shall refer to them as theories, and will select a candidate for each, I am of course aware of the internal debates that take place in each camp and the diverse range of alternative proposals within each category. Still, it continues to make sense to divide the land as I do, I think, for the purpose not merely of convenient classification, but also in response to the conceptual and logical hallmarks of the diverse range of alternatives. There is a clear sense in which there are still four fundamental families of philosophical theories concerning causation. There is yet another set of approaches, as we shall see, which cannot easily be subsumed under these four, but they do not amount to anything like a theory. They are rather expressions of some expedient methodologies for successful causal inference. I have nothing at all against successful methodology, quite the opposite: I am in fact in sympathy with those methodological approaches, and I shall align my views with them in some fundamental ways. Yet, unlike some of their defenders, I do not suppose these methodological approaches can replace philosophical theories of causation, nor can they carry out the sorts of conceptual work that those theories aim to do.

My plea will rather be for something akin to deflationism: the view that there is no fundamental theory of causation that can entirely capture the concept. The best such a theory can do is to closely dovetail with our use of the concept, i.e., with the practice of causal inference. I have defended a similar deflationism regarding other concepts, such as representation (Suárez, 2004a). But there are differences. For causation I support a more radical yet substantive sort of pluralism: there are different sorts of causes, acting in different ways in different contexts, yet the underlying methodology for their discovery in practice turns out to be roughly the same. So, it makes rational sense for someone interested in the role such causes play in inquiry to focus on the methodology to the detriment of philosophical theory. Call this view *quietism*, rather

[1] I am thinking here mainly of David Lewis' (1973, 1986), which is partly a counterfactual and partly a regularity theory, and Wesley Salmon's (1984) which is partly a probabilistic theory and partly a process theory (at least prior to the emergence of the Dowe (1995)-Salmon (1997) conserved quantity theory).

than *deflationism*, since it does not enter the game of denying a nature to causation, it simply accepts its manifest multiplicity, and then chooses to stay largely silent regarding its essence.[2]

The four types of cause, or aspects to causes, that I see acting in the world correspond to those types defined by the regularity, probabilistic, counterfactual, and process theories of causation. That is, each of these theories (rather each a family of theories) addresses a type of causal action or agency, in my view, even though there is significant argument regarding how to characterise each of the types. Hence, these four theories are – at worst – rough approximations to what may be referred to as regularity, probabilistic, counterfactual, and process causation. [3]

1.2. Regularities

Regularity theories of causality originate in Hume (Hume 1739: book I, part III, section XIV [1978: 169]) according to whom causation is "[a]n object precedent and contiguous to another, and where all the objects resembling the former are plac'd in like relations of priority and contiguity to those objects, that resemble the latter." The account can thus be summed up in two simple conditions, which Hume applied to types of objects, but which are nowadays more typically applied to event-types. We may thus say that an event a of a certain type A ($a \in A$) is a *regularity cause* of an event b of another type B ($b \in B$) if and only if:

i) a precedes or occurs ahead of b and
ii) events of type A are regularly followed by events of type B.

This simple Humean regularity account has the virtue of simplicity. It is intuitive in the sense that it corresponds to our ordinary experience of causation. And while it is a substantive theory that aims to define the notion of causation, it is also

[2] While the quietist view regarding causation in science is a new option, as far as I know, radical pluralist attitudes are widespread. Maziarz (this volume) canvasses the extant pluralisms well.

[3] This is perfectly in line with the Illari-Russo (2014) 'causal mosaic' thesis regarding types of causes – even though my selection of specifically four types of cause is not one they would necessarily endorse. I am by contrast less sanguine regarding a causal mosaic of *methodologies*, as shall become clear when I take up the defence of interventionism.

rather non-metaphysical in the sense that there is no appeal to any non-observable notion in the definiens. The two events in question (a and b) are putatively observable, as are the events of each type that can be observed to be regularly followed by each other.

Nonetheless, as is well-known, the theory is subject to many counterexamples which make it untenable, at least in its basic formulation above. The two independent conditions i) and ii) above are neither necessary nor jointly sufficient. The first condition notoriously requires that all causation be forwards in time, and there are physically and logically possible counterexamples to it. In physics, tachyonic particles travel backwards in time in some legitimate frame of reference. Conceptually, Michael Dummett (1954) famously argued that causation does not always 'look to' the future but can 'look to' the past. And physically, relativity theory allows for the possibility of tachyons, which are particles travelling back in time in some legitimate frame of reference (see e.g., Maudlin, 2011 [1994], Chapter 3). The second condition is even more fraught, since requiring constant regular conjunction rules out indeterministic or probabilistic causation, which may have been unknown to Hume, but is widely regarded as fundamental since the 'emergence of chance' in the 19th century. As for the two conditions being jointly sufficient, it is evident that any event c that is co-occurrent with both a and b and temporally intermediate (such as, for instance, a by-product of a that regularly predates b) will also satisfy both conditions while not being by definition a cause of b. (The classic example concerns a barometer's signalling 'Low' predating and being regularly associated with stormy weather, when in fact both are independently caused by low atmospheric pressure). Hume may deny the distinction between being a genuine cause and mere co-occurrence, but it is concerning that his definition makes it impossible to distinguish, and discover, spurious associations.

John L. Mackie (1974) developed this theory further, in terms of what are known as INUS conditions. The illustrative example is the lighting of a match that causes a fire. The lighting of the match is an insufficient but non-redundant part of an unnecessary but sufficient condition for the fire. The fire could have been caused by altogether different means, and the lighting of the match is not sufficient, since other circumstances (the presence of oxygen, etc) must obtain as well. It is clear that particularly the second problem pointed above does not go away: Mackie's emphasis on necessary parts of sufficient conditions rules out indeterminism. Mackie tried to address the problem by means of statistical laws, but the solution remains controversial. There are also difficulties with spurious correlation: The same structure of a cause *a* with two effects *b* and *c* that compromises Hume's definitions can also be a counterexample to the INUS theory. Finally, it is hard to see how Mackie can account for the asymmetry of causation (this is the fact that there is a causal arrow from cause to effect, which is non-symmetrical; and it is unrelated to the issue of whether there can be backwards in time causation). The INUS conditions carry no inherent asymmetry, so this would have to be imported 'from the outside'.

1.3. Probabilities

An indeterministic account of causation where causes do not necessitate their effects was provided by Hans Reichenbach (1956) and, later on, by Patrick Suppes (1972). The idea is simple and involves probabilities. Rather than requiring that a cause always be accompanied by its effects, a probabilistic theory of causality takes it that causes *raise* the probability of their effects. An elementary expression would be that *a* is a *probabilistic cause* of *b* if and only if:

i) *a* precedes *b* and
ii) *a* raises the probability of *b* from *Prob (b)* to *Prob (b/a)*, where *Prob (b/a)* $\geq$ *Prob (b)*.

Reichenbach is celebrated for his elaborate attempt to show the direction of time to be determined by the direction of causation, thus making the first condition essentially redundant. Reichenbach aimed to do this through his *principle of the common cause*, which is essentially a requirement that every correlation between two event-types be causally explained by either direct causation between the events, or a common cause that underlies their correlation, where common causes must satisfy a notorious screening off condition. (This is a condition that renders the correlation ineffective when conditionalized upon the common cause: *Prob (b / a & c) = Prob (b / c)*, where 'c' denotes the putative common cause). Controversy rages to this day as to whether or not Reichenbach succeeded, so I have stuck to an expression closer to

Suppes' later version of the theory. [4] Nevertheless, the theory is clearly an improvement over the regularity theory in at least the sense that it is not wedded to any necessitation relation (or, for that matter, any logical condition of any sort) between causes and effects. Indeterministic causation is the norm, according to this theory, with deterministic causation merely accounting for the extreme cases where *Prob (b / a) = 1 or 0*.

The probabilistic theory of causation also delivers us from the problem of asymmetry since it has built into it the asymmetry of conditional probability. That is, the fact that *Prob (b) ≤ Prob (b / a)* does not in any way imply that *Prob (a / b) ≤ Prob (b)*, so causation only flows one way and, moreover, according to Reichenbach, only flows forwards in the direction of the arrow of time. Nevertheless, there are again several counterexamples. Perhaps the best-known ones come from Wesley Salmon (1984) and Nancy Cartwright (1979). Salmon imagines scenarios where a causa happening actually lowers the probability of its effects. Suppose a golfer hits a ball in the wrong direction, but luckily it bounces on a nearby tree and holes in one. It would be hard to deny that hitting at the tee was a cause of holing it in one. Yet, on a probabilistic analysis, Prob (holing in one) ≤ Prob (holing in one / hitting in the wrong direction). Cartwright used an example due to Hesslow to show that the contraceptive pill, a common cause of the prevention of pregnancies and thrombosis in women, can have its effects statistically masked by the fact that the effects are in turn themselves causally related (getting pregnant is also a probability-raising cause of thrombosis). Here, again, by construction, we can have causation without any change in the overall probability of the effect. Attempts to patch up this definition of causation have had mixed fortunes at best, and probabilistic causation remains open to a diverse set of counterexamples.

1.4. Counterfactuals

Hume notoriously defined causation twice later on, in the Enquiry, where in one sweeping paragraph he wrote (1740, section VII: 60): "we may define a cause to be an

[4] Sober (1983) develops the notion differently in the context of evolutionary biology.

object, followed by another, and where all the objects similar to the first are followed by objects similar to the second. *Or, in other words, where, if the first object had not been, the second never had existed*." The latter sentence is no qualification of the first, but outlines a different counterfactual aspect (Lewis, 1973, 1986). In the simplest form of the counterfactual account, an event b ($b \in B$) causally depends on an event a ($a \in A$) if and only if:

i) *were a* to occur, then *b* would occur, and
ii) were *a* not to occur then *b* would not occur.

The first condition is trivially satisfied for actually occurring events, and causal dependence between occurring events boils down just to the application of ii): An event *b* is causally dependent on an event *a* if and only *had a not occurred then b would not have occurred*.

The counterfactual account has many advantages over the regularity account, which were beautifully explored by Lewis (1973, 1986). First, it expresses no time direction to the notion of causation, so it has conceptually no problems with backwards in time causation. (Still, Lewis was adamant that the theory could also explain the typicality of forward causation by ingeniously appealing to 'local miracles'). Second, it can reveal both confounders and spurious associations. Thus, in the case of a by-product c of a cause a of some event b, which we saw the regularity account cannot manage, the counterfactual account has no problem since although a, b, and c all satisfy the first condition, only a and b satisfy the second condition, since c can occur for reasons entirely unrelated to a, and therefore also unrelated to b. Storms are causally dependent on low pressures but not on barometers' altered positions – which may be due to malfunctioning or any other intervening cause.

Yet, there are many problems with counterfactual accounts, which have been much discussed in the last few decades. They mainly concern local miracles, transitivity, and, perhaps most importantly, pre-emption. I shall only quickly review the latter two here. Transitivity of causation follows from the evident transitivity of causal dependency: if a causally depends on b, and b causally depends on c, then a causally depends on a. Yet, one can find multiple counterexamples of transitive causal dependencies that do not constitute causation. Thus, Peter Menzies and Helen Beebee (2019) describe an informally discussed example due to Ned Hall. A mountaineer ducks to avoid a falling boulder, and thus continues her stride up the mountain. The continued stride causally depends on the ducking, and the ducking causally depends on the falling boulder, but it does not seem to make sense to say that the boulder falling caused the stride to continue. The issue of pre-emption is compounded with difficulties in accounting for chancy causation, which Lewis attempted to do by building single case chance functions into the consequents of the counterfactuals. Thus, an event b causally depends on an event a, if and only if: were a to occur then the single case chance of b is *Prob (b)*= *x*, and were a not to occur, then its chance is strictly less (i.e., it is *Prob (b)* = *y*, where $y < x$). If another event *c* causally depends on *b*, then its probability relative to *a* should be lesser still and cannot be greater. Yet, as we saw in the previous section, causes need not raise the probability of their effects; and there are cases where b actually not happening can actually raise the probability of c.

1.5. Processes

The theories reviewed so far tend to assume that causation is a relation, and its relata are events, or propositions stating events. The variables {a, b, c} so far employed denote such events, since they are bi-valued random variables that take value 1 or 0 depending on whether the events in question take place or not. But one may wonder if causation is a relation between events. A well-known and entrenched alternative is the idea that causation is rather a process that traverses some space in some duration of time. Events are then just the intersections of such processes, or an abstraction of such processes to a given instant in time. The thought that an adequate theory of causation ought to invert the primacy of these ontological categories is ancient, was prescient in Whitehead's process metaphysics, and was turned fully into a theory of causation in contemporary terms by Wesley Salmon (1984) and Phil Dowe (2000).

The central challenge for such a theory is to distinguish genuinely causal processes from mere spatiotemporal continuities. There are plenty of examples of the latter. A much discussed one involves a torchlight projected upon a wall. One can get the light to rotate around the wall, exhibiting spatiotemporal continuity, yet the causal process is the one carrying light from the torch to the wall, not the projected circles of successive dots of light appearing on the wall. The intuition here is clear but what sort of principles can do them justice? Salmon initially developed a theory based upon a Reichenbachian mark-transmission criterion (in Salmon, 1984), which he then improved upon in a series of later papers, and eventually abandoned in favour of Phil Dowe's conserved quantity theory. However, let history not detain us. It has been chronicled by different authors (including myself in the context of attempts to make sense of quantum non-local correlations in Suárez, 2004b, 2007). The conserved quantity theory takes it that i) a causal process is a world line of an object that possesses a conserved quantity, and ii) a causal interaction is an intersection of world lines that involves exchange of a conserved quantity (Dowe, 2000: 11). This simple formulation overcomes various objections to the earlier mark-transmission criterion, but it has its own limitations; quite clearly it fails to apply to any phenomenon or system that cannot be described as a process capable of conserving some physical quantity. There are different reasons why this may not be possible. The system may lack a worldline (i.e., it may not evolve in a continuous trajectory in spacetime) or it may have a worldline but not one that obeys a conservation principle (perhaps because there is no coherent description of the system as physically closed). The sort of processual causes described by the theory require a spacetime background and some conservation principle. Both may be elliptical in some sciences such as astrophysics, molecular chemistry, or evolutionary biology, whilst being explicit in mechanics and the theory of relativity. But other areas, particularly in the social sciences are more hard-pressed. What is the process underlying, e.g., the Philips' curve (the celebrated hypothetical law that relates rates of unemployment and inflation in a national economy)? It is hard to tell. Even if one could find such a process in physical spacetime, it would be hard to demonstrate that it expresses an actual conservation law (and, in fact, most economists believe it to be empirically false). And so on, across the social and medical sciences.

2. Causal Pluralism in the Natural Sciences

None of the above well-known philosophical theories of causation (even in their most sophisticated versions beyond the elementary presentation above) is fully adequate, as we have seen: They are all subject to potential counterexamples. It is then tempting to argue that causation is not one but many things under the same label (Cartwright, 2004). Indeed, this pluralist thought is not new. Many have defended varieties of causal pluralism before, including Sober (1984), Hall (2004) Cartwright (2004), Hitchcock (2003, 2007), Godfrey-Smith (2009), Reiss (2011), Illari and Russo (2014). Curiously enough, to my knowledge, no one has defended pluralism concerning the four main philosophical theories described in the first section, nor have similar quietist arguments for pluralism been advanced before. [5] The first section defends the plurality of four causes, or aspects to causes, in a few examples from the natural sciences (physics and biology). The second and final section argues that our methodology for causal discovery is interventionist in all cases.

2.1. Causes and their Types in Physics and the Life Sciences

There are instances of all four types of causation in the natural sciences, where effective causes are complex mixtures of some of these types. For although the types are distinct, they are not incompatible. The definitions apply to aspects, or properties, of causes; but, as Illari and Russo (2014) argue, many causes exhibit more than one aspect – indeed a complex mosaic of such aspects. Thus, in physics, classical mechanical forces are regularly understood as causes in both the regularity and counterfactual sense (see e.g., Wilson, 2007). In spacetime theories, including relativity, causes are understood in terms of processes (worldlines within the spacetime light-cone), yet they also exhibit regularity and counterfactual aspects (see Fletcher, this volume) And while there has been more scepticism regarding causation as applied to statistical and atomic physics, it is still certainly possible to conceive of the main relations in those domains in causal terms, in either regularity, counterfactual, or probabilistic terms. Beyond physics,

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[5] Hitchcock (2007) comes closest to the same enumeration of theories, but with some critical differences, particularly as regards the manipulability account, which he takes to be a theory and, as will become apparent, I do not; while Reiss (2011) discusses varieties of what he calls Wittgensteinian pluralism, some not unlike my quietism, but applies them to a different set of approaches to causation. The rest of the proposals differ markedly from mine regarding both the varieties of causation, and the type of 'quiet' pluralism.

in chemistry, reactivity mechanisms are probabilistic processes – they are both processual and yield probabilities as the conclusions of their processes. Finally, in the life sciences, there are an array of different causes; in evolutionary biology, natural selection has often been described as a cause – and the jury is up as to whether this is a counterfactual, probabilistic, or process type of cause: It seems to exhibit all aspects. In ecology, reciprocal causation is best understood, I argue, as a form of dynamical process. And so on.

Let us briefly focus on two examples from quantum mechanics and evolutionary biology. They are not free from controversy, both as regards whether causal notions apply at all, and if so, what kinds of causes are involved. But this is partly why I choose them. Whatever causes are involved in both domains, I argue, we go about discovering them in a similar way, in accordance with a broadly interventionist methodology. That we find out the underlying causes in the same way is what both cases have in common, and the reason why causal issues are undoubtedly at stake.

Thus, in quantum mechanics, the debate has been raging as to whether in Einstein-Podolsky-Rosen (EPR) scenarios, causal notions apply; and if they do, what exact causal conclusions follow. Bell's theorem (Bell, 1964, 1966), and its experimental confirmation in the now rightly celebrated experiments by Alain Aspect and his collaborators (1982), led many philosophers to conclude that the EPR correlations are brute unexplained facts of nature that are in some fundamental way uncaused. Van Fraassen (1982 [1989]) best expressed what many took to follow from an application of Reichenbach's (1956) principle of the common cause to the correlations between spacelike separated measurement events in the distant wings of an EPR experiment. If spacelike separated events cannot be causally directly implicated (as orthodoxy would have it, since this may require a signal travelling at a speed greater than light), then neither measurement outcome event can be said to cause the other in an EPR experiment. However, the violation of the factorizability condition in Bell's derivation of his theorem also prevents any Reichenbachian common cause explanation of the two distant measurement outcome events. More precisely: if common causes screen off, as required by Reichenbach's principle of the common cause, then the quantum state of the entangled particle pair at their emission cannot be a common cause of the outcome events. That is, although the measurement outcome events both lie within the light cone of the ejection event at the source, the state at the source is not the common cause, because it does not screen them off. It seems to follow that the EPR correlations are uncaused primitive facts of nature (Hausman, 1999; Hausman and Woodward, 1999).

But this conclusion has since been revealed not to be sufficiently attentive to the causal notions at play, and to the intricacies of the interventionist methodology that they require (Suárez and San Pedro, 2011; Suárez, 2013). The presumption was always that whatever causation is involved must be probabilistic, hence the factorizability condition in Bell's inequality ought to be interpreted in light of Reichenbach's principle of common cause. Such a presumption has proven dubious, and most contemporary analyses point towards counterfactual or process causes instead (see Maudlin, 2011 (1994), and Suárez, 2004b, respectively). In an EPR experiment, the separate spin measurement outcomes depend on each other in a counterfactual way, just as would be expected; and the processes that take each particle from the source to the location where it meets its corresponding detector is a causal process both according to the mark-transmission event and the conserved quality theories of process causation. As a result, it is not in fact difficult to devise causal models for the EPR correlations that explicitly contradict at least some of the premisses involved in philosophers' putative arguments against causation in the quantum realm (Maudlin, 2011 (1994): Chapter 5; Suárez, 2004b, 2007, 2013; an earlier direct cause model for EPR was provided by Cartwright and Suárez, 1999; more recent discussions in support of quantum causation for EPR phenomena along these lines include Shrapnel, 2019, and Naeger, 2022).

The second example concerns the notion of fitness in evolutionary biology. Here I can be even briefer since the controversy between 'causalists' and 'statisticalists' is well-known (Matthen, 2002; Walsh et al, 2017). According to the former, fitness is a causal explanatory property of individual organisms (or genes, or traits, or whatever is the unit of natural selection), in some way or other associated to the expectation of the organism's successful mature offspring. According to the latter, however, fitness is just that very expectation – the expected value of the statistical distribution for successful offspring for organisms of this type in a representative population. The former think of fitness as a causal property of tokens; the latter think of it as a merely descriptive statistical representation of certain traits in a population, one devoid of causal power, yet explanatory in its own right. But how do we go about discovering causes? Both ‘causalists’ and ‘statisticalists’ would agree that the right methodology is interventionist – they just disagree over whether it is applicable to evolutionary fitness. Thus, for the former, we find out an organism’s fitness by intervening in such a way as to generate a change in whatever properties or traits are associated to fitness in an environment; we then check whether this has relevance for the expected number of offspring. If fitness is responsive to that expected value, it certainly ought to co-vary as required. The causalist believes it does; the statisticalist denies it. For the latter, the only relevant quantities are statistical proportions within a population – when they change the remaining statistical properties change, but this is not out of any causal relation between organisms – the only relations that can be deemed ‘causal’ here, if any, operate at the statistical level of populations. A way to solve the controversy is then to refuse to identify evolutionary fitness with just any property of individual token organisms / genes / traits, or any property of statistical populations, but to identify it with both and their generative relation (see Sober, 2011 and Suárez, 2022 for proposals in this direction). In these pluralist approaches to fitness, there exist both ‘proximate’ and ‘ultimate’ causes (Mayr 1961) and we find them all out by the same interventionist methodologies.

2.2. Manipulability and Causal ‘Quietism’

If there is a multiplicity of different causes, as it appears to be the case, we shall like to know what it is that they have in common, besides the name. If ‘cause’ is not to be an entirely nominal class, should there not be something that links all the different causes, or subsumes them under a particular conception? The easy answer is that there exists a supra-theory that accounts for all of these classes and subsumes them all under one unique definition. And that has indeed been the premise under which the debate has been run so far, to no effect. What’s more, if there is anything that all the pluralist authors mentioned in the previous section share, it is precisely their rejection of this easy answer. There is no unique definition of causation, and no essence to all these causes, which they may be seen to share. What then is the glue that ties them all together and merits them being a ‘cause’? My suggestion is not to look for the answer in the metaphysics of causation which, I submit, along with all authors mentioned above, is irreducibly plural. Instead, following Woodward (2014), I propose that we look at the functional role these notions play in the methodology of causal discovery. In particular I suggest that we look at Woodward's manipulability account (2003) as the needed functional account of the methodology of causal discovery.

On this view the manipulability account is neither in the business of providing a metaphysics for causation, nor is it furnishing us with an epistemology. It neither tells us what causes fundamentally, or in essence, are, nor does it tell us fundamentally how we humans can have justified warranted knowledge of them. It just merely describes the most general methodological rules that allow us to discover causes in practical inquiry. The manipulability account simply informs our methodological practice.

If it so happens that we go about finding out causes in very much the same way, *regardless of what sort of causes these are*, then there is something functional that all types of cause share, namely the methodology of causal discovery. I take it that this would provide enough solace for those who want to go beyond a mere nominalism of causal kinds but lack a universal theory to subsume these kinds. The common core shared by all regularity, counterfactual, probability and process causes is the methodology of causal discovery that we apply in order to discover them. I call this view 'quiet pluralism' because it stresses that there is nothing to say about the essence, or constitution, of the causal relation in all generality. As a way to resolve the mystery of their shared nature, the quiet pluralist just recommends that we look at what we do with causes instead. This is certainly a Wittgensteinian thought, but it is not any of those that are conventionally associated with semantics, whether Wittgenstein's middle period inferentialist semantics or the use-meaning theories of his later *Philosophical Investigations*. What is recommended is not an engagement in semantics since our purpose is not to define the notion of cause. Instead, I am suggesting that, in our search for an understanding of causation, we would be well advised to give primacy to scientific methodological practice over any concerns in epistemology, metaphysics, or semantics. [6]

More recently still, different authors are turning their attention to the ontological presuppositions of the methodology of causal discovery (Andersen, this volume;

[6] I cannot presume that Woodward would agree, but this is at any rate in line with Kitcher's (2023) recent diagnosis of the misuses of philosophy, and his (i.e., Kitcher's) own evaluation of Woodward's approach to causation as the best way to overcome them.

Weinberger, Porter and Woodward, forthcoming). There is a legitimate debate to be had as to whether this entails a return to metaphysics. Thus, Andersen speaks of the 'foundations' of causal inference, and she claims it requires a minimal metaphysics to get off the ground. Weinberger and Woodward, by contrast, choose to speak of the 'worldly infrastructure', the minimal set of conditions that it takes to get the interventionist machinery off the ground, including all relevant notions, such as cause (recall that interventionism is not an analytical theory of 'causes' but, on my account, merely a methodology for causal inference – so there is no circularity involved), and intervention, exogenous variables and so on. Minimally, they claim, this worldly infrastructure requires the causal relata to be representable as random variables (even if bivalued variables, for yes-no events or processes), and to possess a certain structure that makes the *Causal Markov*, *Modularity*, and *Faithfulness* conditions applicable. On this debate, I side with Weinberger, Porter and Woodward in the view that the 'worldly infrastructure' does not amount to any metaphysics, and carries very little, if any, modal content (in terms of possible worlds and the like). [7] It is rather merely the description of the contingent features of reality that minimally make causal inference possible, wherever that sort of inference is in fact possible, in the actual world. All of this is true even though, or perhaps precisely because, the evidence that we can ever possess for any causal claim is highly context dependent, even though the claim itself semantically need not be contextual in any way (Suárez, 2014). In other words, the term 'cause' may be analytically defined by each of the four theories presented in the first part of this paper; but any evidence for the existence of any causes that we may possess, in any context, does not differentiate between these types. In a context where the worldly infrastructure does not obtain, for example, our causal knowledge is severely impaired. This does not mean that there exist no causes in that context's domain – it just means that we have no effective tools at our disposal to discover them.

The two case studies that I have presented in this paper exemplify this well. The dispute regarding quantum causality is about whether interventionist methodologies are applicable to EPR-like phenomena at all. Similarly, different approaches to evolutionary

[7] I do concur with Andersen, though, that this sort of analytical metaphysics is anachronistic and rather odd from a historical point of view. It makes no sense before the turn to conceptual analysis in the 1950s, never mind in the 19th century eyes of someone like, say, Charles Peirce – and it may be the case that we would be better off returning to 'metaphysics' as practised at that time. See Andersen (2017) for a different approach to the metaphysics of causation that is more in line with Peirce's pragmatism.

fitness differ on whether interventions can possibly bring about causal knowledge, not merely knowledge of statistical correlations. The sceptics in both cases claim interventionist methods fail, because the worldly infrastructure that is required to get them off the ground is absent in these domains. Yet, every participant to the debate agrees that 'causes', if they exist, are to be discovered through these methods; so, when the methods fail to obtain causal knowledge becomes unassailable. In other words, all parties implicitly or explicitly agree that the key to the concept of 'cause' in practice (the glue that joins all four kinds of analytical causes where they obtain) is the methodology we follow in order to discover them.

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