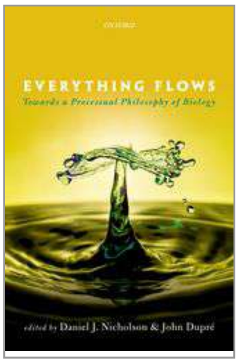

Everything Flows: Towards a Processual Philosophy of Biology

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Dispositionalism

A Dynamic Theory of Causation

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Abstract and Keywords

Since the advent of modern philosophy, causation has been treated as a relation between two separate events. Any worldly dynamism is then provided by the succession of essentially static events. Recent decades have seen a revival of interest in powers, but this has been hampered by an acceptance of many of the presuppositions of modern philosophy, most conspicuously those of Hume. Simply placing powers on top of the static Humean framework will not do. Causal dispositionalism offers a more dynamic notion, where an instance of causation involves a unified process rather than a relation between distinct events. This theory has a number of advantages. It can account for change as well as stability, long- and short-lived processes, genuine complexity and real emergence, non-linear interaction of causes, extreme context-sensitivity, and contrary powers. This is a more plausible framework for understanding causation in biology, ontologically and epistemically.

Keywords: biology, causation, disposition, dynamism, mutual manifestation, powers, process

1. A Received Orthodoxy

David Hume’s biggest influence on the philosophy of causation was not the notion of constant conjunctions, nor was it the theory of counterfactual dependence. As is well known, these two different accounts of causation are both to be found in the first *Enquiry*—indeed, within the very same paragraph (Hume 2007 [1748]: VI, 56). There is, however, an idea of an even greater generality and at a higher level of abstraction that has pervaded much more post-Humean thinking about causation than simply regularity and difference-making theories. This idea has become so orthodox that in most cases it is simply assumed as the required starting point without any discussion. The unexamined assumption is that causation is a relation that relates two distinct events, objects, or existences.

The linguistic expressions of English seem to reinforce the assumption. The lighting of the fuse caused the explosion; dropping the vase caused it to break; ingestion of arsenic caused the victim’s death; colliding with the iceberg caused the ocean liner to sink; and so on. These causal statements are all conducive to the received orthodoxy as it’s easy to see within them a form *aRb*. *Prima facie*, they describe one event followed by another where the two events are causally related. The causal relation is clearly not merely temporal succession, for an event preceding another is not always its cause. There is thus a whole philosophy of causation that is about correctly identifying what the correct causal relation is that holds between some but not all ordered pairs of events. Some say the relation is an INUS condition (Mackie 1993 [1965]), others that it is a counterfactual dependence involving similarities between possible worlds (Lewis 1986 [1973]).

The orthodoxy immediately suggests a disunited view of the world: that it consists in a succession of distinct, wholly discrete events. The world might not be that way, though. Suppose that things are more unified, dynamic, and continuous and that change occurs in a smooth and gradual processual way. What if, furthermore, this latter view is the one needed in biology to account for causation within, and affecting, living organisms? A problem, we argue, is that, if one begins from the idea that causation has to be a relation between two discrete and ‘static’ events, then it may already be impossible to formulate a satisfactory theory of what causation is and how **(p.62)** it works. The biological case makes this quite apparent. The assumption splits the world asunder into distinct, self-contained fragments, and then tries to find a relation that would stick them all back together again. It is not clear that any relation can do this job. Even if it could, would the world with which we are left—a Frankenstein-world of stitched together pieces—have all the features we require? Would it really be a world of continuity, fit for living biological processes?

Hume urged us to accept a world that was loose and separate: conjoined in some cases, but never connected (Hume 2007 [1748]: VII, 54). He proposed that causation consisted in a complex relation holding between events that consisted of (i) constant conjunction or regularity, along with (ii) temporal priority of cause over effect and (iii) contiguity (Hume 1888 [1739]: I, iii, 14). This gave a causal relation that was enough to explain why we have a psychological habit of inferring the effect from the cause without allowing anything like necessity, which would make the world more connected and less separate. Others have since opted for a stronger relation between cause and effect (e.g. Mellor 1995). But it is the idea of the unconnected world that, we argue, is already damaging enough, no matter what relation one offers to repair it.

There are many different ways in which this Humean view could be developed, and not every way will have all the features that we describe. But let us outline a plausible candidate for the orthodoxy. In the world there is a series of events or states of affairs (Hume says objects). Some of these occur at the same time and many more occur at different times from each other. A ball is blue, for instance; a metal rod is 1 m long; the same metal rod has a temperature of 20°C; a sugar cube is placed in liquid; the same sugar cube dissolves; a rock is pressed against a pane of glass; cryptosporidium is present within a certain human organism; that same human organism is unwell. A key move within empiricist philosophies is to say that in principle any event can follow any other (Hume 2007 [1748]: IV, i). We cannot know a priori what will follow what, as this is a contingent matter. Between any two distinct events, where one precedes the other, those events may be causally related or they may not be. It is thus an empirical matter to discover whether they are causally related.

What it is for one event to be causally related to another is the business of philosophy to decide. Here is where the details can vary. We have already seen Hume's threefold account. Lewis's (1886 [1973]) theory is that, for event A to be the cause of event B, A and B must both occur; and it's also the case that, had A not occurred, B would not either. This amounts, within to the modal realist account, to its being such that, in all the closest possible worlds (in terms of overall similarity) to the actual world in which A did not occur, B did not occur. Suppes (1970) develops the idea that a cause is something that raises the probability of an effect: it has a positive statistical relevance to it. In Armstrong's view, one fact causes another just in case doing so instantiates a contingent law of nature that facts of the first kind necessitate facts of the second kind (Armstrong 1978: ch. 24). In Salmon's (1984) view, a conserved quantity is passed from the cause to the effect. In these theories, there is nothing in the essence of causally related things that makes them be causally related. Whether or not they are just depends on the contingencies of the world, which it is the business of science to discover. We do not have the space here to do full justice to any of these views, or to consider the many other theories of causality on offer.

(p.63) This orthodox picture, while widespread, should be challenged, we argue. In the first place, we can question its appeal on empirical grounds, in particular on the issue of how well it suits cases of causation that require continuous change, biology being such a case. Second, we challenge also the metaphysical adequacy of this account. In particular, if one prefers a metaphysics of causal powers to a Humean mosaic of distinct existences, one should have a more dynamic and process-like view of things. As others have noted before, particularly Martin (2008: 46), this would seem to require an overthrow of the old two-event model.

2. Causation in Biology

Let us now consider some of the lessons that can be drawn from biology. First, biology is notable for its requirement that organisms be in a state of continual change. Movement, flux, development, and process seem essential to life in that to cease to change means death. An explanation for this may be that we have to account for living organisms in terms of functioning (Rosenberg 2008: 513), which has to involve activity. Where different animals have a heart, for instance, the architecture or physical features of the organ does not matter as much as the active, life-sustaining function that it is to perform. This is not to deny that there are cases of relative stability that are important for life too, such as body temperature for humans being within a narrow range close to 37°C. But this stability is also one that is understood to be caused by underlying functions, including homeostatic processes (sweating to cool down; shivering to warm up). An organism's persistence does not depend on being kept in a single state but on being maintained through numerous processes: the continual beating of the heart and breathing of the lungs, a cycle of dehydration, hydration, and absorption of water, metabolism, the ingestion of food and its conversion to energy and waste product, movement around an environment that provides life-sustaining resources, synthesis of vitamins from a variety of sources (such as the sun), sentient and sapient activities, and so on.

To live is thus always to be active to at least some degree. Are there any exceptions? One might argue that it is possible in principle for an organism to undergo a period of motionlessness, such as being in deep hibernation, and yet still be living. But this is not really an exception. In hibernation, body temperature drops and the heart and breathing rates slow considerably; but they do not stop completely. Metabolic activity remains. Thus there is a lowering of degree of motion, but not a cessation of change. This is true even in the extreme cases of suspended animation or cryogenization.

Life suggests a need for *continuous* change. Even the slightest moment of changelessness results in death. Yet the standard assumptions behind many theories of causation accommodate this poorly. Causation is often depicted as relating *changeless* relata—static events or states of affairs—that are wholly temporally distinct. As Bennett (1974) argued, Hume committed to a discrete view of space and time so that causes and effects would not be connected. On such a view, there are smallest units of time and space, which must be indivisible and point-like. This commitment to space–time points survives in Lewis's metaphysics (Lewis 1986c: ix–x). Absurdities **(p.64)** arguably accompany the view, though, as it is hard to see how there can be temporal succession in a series of unextended points unless there are temporal gaps between them. A requirement of temporal gaps would be contrary to the initial analysis, however.

Even setting that aside, and granting that a succession of point-like times is possible, the view entails also that any property instantiated at a discrete time must be changeless or static. This is because change requires duration; and a moment of time, on this view, has none. The subsequent theory of causation must therefore posit a relation between static relata.

This gives us an account in which change is supposedly produced somehow by an ordered succession of changeless states, as in perdurantist theories of persistence (Lewis 1986b: 202), which will be discussed further below (see also Mumford 2009). The challenge from biology is how well this sits with its requirement for continuous change. Wouldn't perdurantism tell us that organisms are changeless at each point in time, merely progressing from one changeless state to another and then another? It is arguable that this makes change something of an illusion, like the one created through the rapid succession of projected still images, as in old-fashioned analogue film, which shows twenty-four still frames per second.

In addition to this need for continual change, let us note some of the other features of causation in biology, though we will not dwell on these at length. One is that there is a hierarchy of processes occurring simultaneously but on different timescales. Evolution is a long process compared to a complete life cycle, which in turn is much longer that the causal process in which damaged flesh is repaired. Compared to all these, a sneeze is very sudden. A fast process such as a sneeze can, however, play a significant role in a slower evolutionary process. An ability to rapidly expel irritants from the nose, and which can be passed on to offspring, provides an evolutionary advantage. Can we have a single theory that causally explains such overlapping hierarchical processes?

Next, consider the versatility of causes in biology. Genes can take on multiple roles, which is advantageous to survival as they provide back-up mechanisms that ensure the maintenance of vital processes. A well-known example is a famous study involving the Drosophila, which had its eyeless gene removed and subsequently lost its eyes. Within a few generations Drosophilas got eyes again, though without having the gene back (Webster and Goodwin 1996: 87; Skaftnesmo 2005: 72; see also Leiserson et al. 1995). Other genes had apparently taken on a role that was needed by the organism as a whole.

Notably, no biological system is 'closed', and this is an essential feature of its persistence (see Lewontin 2001 [1983] and chapters 7, 8, and 18 here). An organism might be 'organizationally' closed (Mossio and Moreno 2010), but this does not mean that it is causally closed, receiving no external inputs. Symbiosis is required, for example (see Gilbert 2014 and chapters 1, 5, 9, 10, and 15 here). Bacteria are needed by humans and other animals to perform certain functions such as digestion, and it seems at times that there are no clear boundaries between organisms. If an animal cannot survive without the bacteria in its gut, there is a sense in which the bacteria are part of the animal. An organism as a closed system would be, again, a dead organism. Air, sun, food, and symbionts are all needed for regular functioning. In contrast, some standard theories of causation entertain closed-system idealized worlds, such as where there is just one isolated object that collides with another.

(p.65) We also find in biology an inapplicability of the mono-causal model, which is where there is one cause for one effect. The two-event philosophical view of causation encourages such a model. Instead, in biology we are used to seeing multiple causes of any change: a feature known in genetics as polygeny (Molnar 2003: 194). This causal complexity is emphasized by complex adaptive systems (CAS) theory (see Holland 1992) and by developmental systems theory (DST) (see Oyama et al. 2001 and chapter 11 here), both of which are critical of overly simplistic one-cause models, especially in genetics.

We could go on and mention features such as causation by absence (for instance, where absence of water can kill a plant or animal), the contest and counterbalancing of contrary causal powers, and the multiple causal explanations that seem available for biological phenomena. But we have said enough already to illustrate the complexity that biology must account for in order to explain how life is sustained through ongoing processes of continual change. The standard two-event model, we claim, does not handle this complexity well, offering us just more and more of the same discrete two-events causally related. It was because of its complexity that we took biology as the paradigmatic science in earlier work (Mumford and Anjum 2011: ch. 10)—instead of physics, for instance, which often offers mathematized descriptions of artificially closed systems. Although this may be useful in some branches of physics, it is difficult to draw general lessons for causation in other sciences.

It is one thing to criticize the standard orthodoxy on causation or claim that it is ill suited to some domain. But what, it may be wondered, is the alternative? If there was no credible option but the standard picture, then it would need to stand, perhaps with some adaptation or amendment. However, there *is* another option: a dynamic theory of causation that is a better fit with the needs of biology. We will now go on to describe one such account, namely *causal dispositionalism*.

3. Dispositions and Processes

There is a close connection between dispositional approaches to causation and process metaphysics, though this has not always been highlighted (on process theories in general, see Whitehead 1978 [1929] and more updated views in Sellars 1981, Rescher 1996, and Seibt 2008). One barrier has been that dispositionalists are often working within an Aristotelian tradition, which had a basic substance–attribute ontology. Process metaphysics is often antagonistic to the substance–attribute view (e.g., Bickhard 2011). If we look at Aquinas's account of powers (see Feser 2014: chs 2–3), however, we find something that looks more in sympathy with a process view.

A dispositional account of causation should reject the old stimulus–response model of how causal powers are activated. Such a view comes too close to the two-event model, which we have said should be overturned. Instead, Martin's notion of mutual manifestation (Martin 2008: 48–51) serves us better, though not all dispositionalists have embraced this conceptual innovation. Causation occurs, on Martin's view, when two or more reciprocal disposition partners come together to produce a mutual manifestation. Such a manifestation is an effect produced by powers acting together where none of the powers could have produced the same manifestation by acting alone. Our account of mutual manifestation develops Martin's original **(p.66)** presentation in emphasizing the processual nature of the manifestation. Martin originally illustrated mutual manifestation with the example of two triangles that come together to form a square jointly. We think there are a number of disanalogies between Martin's putative illustration and real causation (Mumford and Anjum 2016). More typically, when mutual manifestation partners are together, it takes time for them to have their full effect, as Kant (1929 [1781]: A203) already noted. During this time, there is a continual development of change—that is, a *process*—that eventually results in a final point, unless interrupted. Beyond this final point, there is, then, no further change unless new mutual manifestation partners are added to the situation.

A simple illustration is the inanimate case of sugar dissolving in a liquid, such as water. As soon as a sugar cube and water come together, the gradual process of dissolving begins. It will continue unless it is interrupted in some way, such as if the container is overturned, or the water is rapidly evaporated. Without interruption, the process continues until it reaches its natural end point, which is for the sugar cube to be dissolved and held entirely in solution. On standard models of causation, we are often obliged to view such a case asymmetrically: most typically we might tend to think of the active liquid dissolving the passive sugar. But Martin is right to emphasize the symmetry—the mutuality—of the change. Being in a causal partnership changes the sugar cube; but it also changes the liquid, which is a sweet solution by the end of the process. This seems to cohere with a principle of reciprocity in causation that is attractive on independent grounds: a cause brings about a change in the effect, but there is a reciprocal change in the cause when the effect occurs (for a similar approach, see Ingthorsson 2002).

The dispositional aspect is important in this account. Dispositions are properties of things; arguably they constitute *the* properties of things (Mumford 2008). They are a thing's causal powers towards manifestations, those manifestations being conditional upon the empowered particular meeting the appropriate reciprocal disposition partners. Crucially, however, these powers are not *just* for the end point of the causal transaction, such as the property of being dissolved that is the end point of solubility. The power is for the whole process that takes a sugar cube from being in liquid to being dissolved. It matters, to count as solubility, how the power gets to its end state of being dissolved. If it did so via some deviant causal chain, for instance, we would not be convinced that this was a case of genuine solubility.

Contrast this with the two-event model. We might be persuaded to understand, as the cause, the sugar cube's being placed in water and, as the effect, its being dissolved. This assists the idea that causation is a relation between two relata. But what happens between the first relatum and the second? It is not as if the sugar goes instantly from being in liquid to being dissolved. There is a gradual natural process of continuous dissolution in-between. If we examine the sugar at any stage intermediate between its being first in liquid and its being wholly dissolved, we should find that natural process going on. Vitally, at any such intermediate point the sugar and the liquid are still together, changing and disposing towards the end result. The dispositionality is thus found throughout the whole process, no matter how small a part, as Aquinas (*Summa contra gentiles* III, 2) noted.

The dispositional account also suggests a greater connectivity between cause and effect than the standard model. We saw that the orthodox view begins with an **(p.67)** assumption that the world's components are discrete, self-contained units, like the tiles in a mosaic. The search for causation is, then, for something that ties some but not all of these discrete units together, though they remain nevertheless distinct existences. Causes and effects are more closely connected on the dispositional account, in the following sense. The placing of the sugar cube in liquid clearly occurs some time before the cube is entirely dissolved, and this appears to support Hume's idea that causes are temporally prior to, and thus disconnected from, their effects. On his view, there can be no temporal overlap at all between causes and effects. It is not even the case that the last moment of the cause can be simultaneous with the first moment of the effect. In contrast, the dispositional view is favourable to simultaneity between the immediate cause and the effect. As soon as reciprocal disposition partners are together, the process that is their mutual effect begins. It takes time to fully unfold but, until the effect is wholly and finally realized, some part of the cause is still present. Again, we can think of the cause as the being together of the water and the undissolved sugar (the cause is not the sugar's being placed in water, which is just the story of how it got there). This cause is in place as long as there is some undissolved portion of the sugar in the liquid. Once it has all gone into the solution, the cause is gone, the process is ended, and the effect is complete. We thus have a temporally extended causal process where the cause is entirely simultaneous with the effect.

This idea is, again, Aristotelian in origin (Aristotle, *Physics* VII, ch. 2), but associated with a metaphysics of substance causation. It trades on the point that, for the cause to bring about the effect, they must exist at the same time. For, if the cause no longer existed, how would it be productive of the effect? (Russell 1992 [1913]: 200 invokes the same argument for different purposes.) Causation looks non-simultaneous, then, only because we conceptually isolate some initial early segment of the causal process and its end point, as if we had a simple relation between the earlier and the later. The problem of causal connection between existences at different times is problematic for any part of the causal process. How could the early part of the process, if it is over, finished, and gone, produce something at a later time if it no longer exists at that later time? Cause and effect are also more closely connected once one couples the powers account with a dense theory of space–time, which we will mention again later on. Although the argument originated in a substance metaphysics, then, it is nevertheless applicable to the more dynamic view proposed here. So applied, it suggests that, rather than being a relation, causation is best understood as a unified unfolding process in which there is gradually less and less of the producing and more and more of the produced.

Can this dispositional account be applied to cases of causation in biology? It should already be clear, we hope, that it can. Consider the process of fertilization, pregnancy, gestation, and child birth in humans, for instance. The two-event model will set the case up as one where an act of sexual intercourse was a cause of a child’s being born nine months later. We can hardly deny that; but this superficial articulation overlooks a great deal of complexity that is essential to the actual causal story. In reality the full nine-month process involves a series of different subsidiary processes, sometimes overlapping or involving thresholds where a subsequent stage in the overall process is triggered. During pregnancy there are a number of bodily changes, such as morning sickness and fatigue as the embryo takes hold in the womb, changes **(p.68)** in the breasts as they prepare to be ready for feeding, changes in physiology as the placenta grows and diverts nutrition to nurture the growing foetus, processes in which the cervix is gradually softened, ready for dilation, and so on. Some of these processes are short-lived and are small parts of pregnancy as a whole. Others, such as hormonal changes in the mother and growth in the foetus, may last for virtually the whole duration. It is clear that this is a natural process that can run its course and reach an end point, but one that is also capable of interruption, either naturally or artificially. Not all conceptions result in births. There is a tendency or disposition for them to do so and this would remain so even if statistically only a minority of pregnancies ended in births. We would argue that the notion of disposing is not reducible to mere statistical matters, as some tendencies are weak and thus manifest themselves rarely. Consider a drug that has only a weak disposition towards some side effect, manifesting itself only in 1 out of 10,000 cases. We can also see that the notion of mutual manifestation is crucial. First, it is relevant with respect to conception, which requires a sperm and an egg to come together and be, both, changed by their interaction. Second, we can see the mother and the foetus as undergoing their own extended processes of reciprocal changes.

To understand how there can be multiple, interacting processes that occur within a bigger nine-month complex biological process such as pregnancy, we need an understanding of how individual simultaneous causes and effects are capable of forming a temporally extended chain. We cannot deny, for instance, that conception occurs before birth, so how does this square with the alleged simultaneity of causes and effects? It is easiest to explain this with two figures. In the first (Figure 3.1), where temporal duration is directed from left to right, we see a single process of change where the cause gradually merges into the effect. We move from only a small part of the process being the effect to the whole of it being so. This could fit the example of the sugar dissolving in water, or a biological case such as a hormonal change producing a change in the breasts of a pregnant woman.

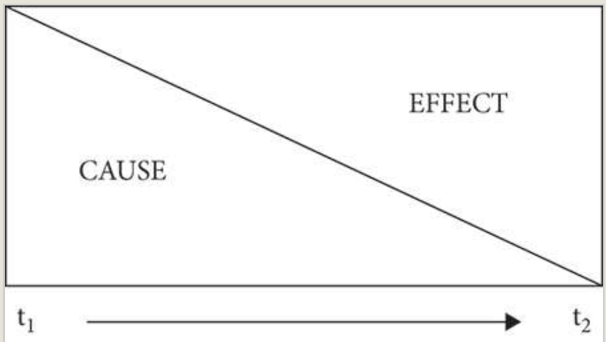

Figure 3.1 Causation depicted as a gradual process

The diagonal line we have drawn indicating the division between the part of the process that is the cause and the part that is the effect is a straight one, which can be taken as indicative of a very steady, linear process of change at a stable rate. In reality, many processes can produce changes in irregular and non-linear ways, there being only a small part of the effect manifested until a threshold is reached. This is the case, for instance, if a rise in temperature produces perspiration but does so to a disproportionally greater extent once a certain threshold is passed.

(p.69) Given that one such causal process involves a change, that process can result in the realization of new emergent properties (for our preferred account of emergence, see Anjum and Mumford 2017). So one process might be the raising of temperature, where the change is a greater quantity of some measured property. Another process might involve the acquisition of a new property, such as a sugar cube's becoming dissolved or a woman's becoming pregnant. On our account, such properties are to be understood as causal powers (Mumford and Anjum 2011: 124–126). Thus processes can result in the realization of new powers, which are then available to form other mutual manifestation partnerships (of two or more powers). We therefore get temporal duration in causation in two ways. One is simply where a single causal process takes time to fully unfold and develop to its natural end point. The other is where the changes of properties in an unfolding process—either at the end of that process or at some point during it—form mutual manifestation partnerships with other powers and initiate new processes. This is how chains of causes can be connected over time, while each link in the chain involves only simultaneity between cause and effect. Thus an act of sexual intercourse that results in sperm ejaculated into the vagina may be seen as one discrete process. The contact between sperm and egg is the start of another, which then also starts a process of hormonal change within the mother, embryonic development, and so on. We thus have a situation as depicted in Figure 3.2.

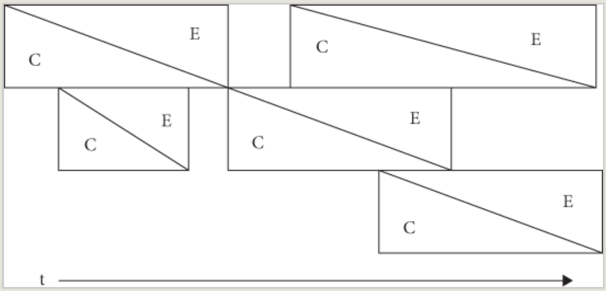

Figure 3.2 Overlapping causal processes

This allows us to answer Marmodoro’s (2013: 550) concern, which was raised against our account of powers. She says that we take the manifestation of a power to be another power, while she thinks that the manifestation is a different stage of the same, first power. But in a process view it can be both. Given that the manifestation of a power produces a continuous change in properties and that properties are understood to be powerful, the properties produced by causes are both the end point of the original power and a new power, available to form a new reciprocal partnership if circumstances allow. Finally, on this topic of extended chains, we have explained elsewhere how sometimes (though not always) causation travels down such a chain, which makes it technically a non-transitive matter (Mumford and Anjum 2011: 167–73); but we will not repeat the detail of the argument here.

(p.70) What of the other features we found to be particularly prominent in biology? We saw that organisms can be regarded as open systems subject to causal interactions with things outside their own bodies, with multiple causal roles for the same genes, complexity, polygeny, with competing and sometimes counteracting powers, and so on. We hope it is clear that the dispositional account can handle such cases.

We allow that mutual manifestation partnerships can consist in any number of reciprocal powers. The two-event model posits one cause for one effect, and it is vital that it does so in order to offer a coherent notion of regularity and/or counterfactual dependence, which are ways the causal relation has been outlined. In the dispositional account, the complexity of causation is embraced, which makes the account compatible with multicausal models in biology such as

DST. The biological process of pregnancy is not just a matter of a sperm meeting an egg and fertilizing it. Multiple other powers come into the account. The egg would not develop into a foetus, for instance, without the presence of a hospitable environment, which offers nutrition and the appropriate hormonal triggers. Because the pregnant organism is an open system, further causal powers can enter the picture, either assisting with the pregnancy (folic acid) or hindering it (tobacco smoke inhalation). The relevant operating causal powers can thus be many. Multiple causal roles are allowed for those powers, because it is clear that the same power, when partnered with different others, can produce different effects (what Molnar 2003: 194 calls pleiotropy). Consider the healthy and nutritional powers of the proteins in peanuts, for instance. When those same powers interact with the bodies of peanut allergy sufferers, they can result in a histamine immune response, sometimes producing severe anaphylaxis or even cardiac arrest.

Given that powers can operate in a non-linear way, we see that their operation is also very sensitive to their strength or degree. Thus a specific quantity of a drug such as paracetamol disposes towards pain relief. Taken in a larger quantity—an overdose—the same power can dispose towards pain. The production of dynamic equilibrium states, often so important for proper biological functioning, can also be explained in the theory. It is possible that two powers that are exercised and that tend in opposite directions can cancel each other out. This may involve a homeostatic feedback mechanism. A so-called zero resultant power will thus tend towards stability; that is, towards a situation in which there is no overall change. While none of the component mechanisms are static, their joint action thus produces relative stability (see Dupré 2014: 15 on the stable/static distinction in biology). Body temperature, levels of hydration, vitamin levels, cell renewal, and so on, all have an element of this kind of dynamic equilibrium in their operation. Human absorption of vitamin C (ascorbic acid), for instance, is regulated by a variety of transporters (SVCTs and GLUTs). When intake is high, these transporters lower the rate of absorption; but, when intake is low, absorption increases markedly. The result keeps a body's vitamin levels within a stable range, despite short-term fluctuations in intake.

4. Static or Dynamic?

Although the term 'event' is used, and the standard model typically takes events to be the relata of causal relations, those events are occurrences more than changes, in a sense that we will now try to make clear. The suggestion is that a static conception of **(p.71)** events is being used (Kim 1976; Lewis 1986a). The standard model is sometimes accompanied by a perdurantist underlying metaphysics where change is something to be explained—perhaps by transitive causal chains—and thus the relata of causal relations have themselves to be changeless (Lewis 1986b: 202–4; Sider 2001; for an overview of the whole debate, see Hawley 2001, especially ch. 3). We interpret this as a discontinuous view of nature, because change is analysed as a mere succession of discrete, self-contained objects, parts, or stages. The perdurantist begins with a metaphysics of static, temporal parts and then tries to explain change through the way in which those parts are arranged. The alternative view is to accept change as basic—something to be found in every segment of a process, no matter how small—and then explain stability, perhaps, as we have already mentioned, as an equilibrium created by counterbalancing powers.

This is the sense in which dispositionalism offers us a dynamic theory of causation. Processes have no motionless parts. Indeed, in no real sense does a process have parts at all; for they can be formed only through the abstraction of a viewer who considers the process. The process is, in reality, an indivisible unity. An event under this conception becomes itself processual. The contrast is with fact-like conceptions, such as those offered by Kim and Lewis. An event, on those views, consists of a property's bearing a particular at a time, such as a ball's being blue at a particular moment. Because no change is needed for this to be the case, it is perhaps better understood as a Tractarian fact or state of affairs (Armstrong 1989). This conception explains why the standard model will usually specify its relata in a non-dynamic kind of way. Causal relations hold between being in water and being dissolved, between being subject to a certain force and taking a new position, between receiving an impact and being broken. These relata do not automatically or obviously involve changes themselves; rather, the change occurs only through the relation of causation that transports us from the cause to the effect.

More naturally, however, we think of events as happenings, and thus as already involving changes. Heating an iron bar causes it to expand, for example, where being heated is what Lombard (1986: 105) calls a dynamic property: one that has to involve change and thus cannot be instantiated at an unextended point in time. However, being heated requires more than just that a certain temperature be realized. What is essential is that there be a direction in the change of temperature—that it be moving from lower to higher temperature rather than vice versa. Thus being heated must involve more than a timeless instant; it must involve a temporally extended period during which there is change. Exactly parallel reasoning applies to the effect, the expansion. Indeed, it is artificial to say that being at a certain temperature causes the iron bar to be a certain length; this makes the relata sound fact-like, and thereby serves a particular metaphysical theory of discrete parts. Instead, we should think of the cause and effect as already being changes, essentially: being heated and expanding. Overall, we find a dynamic account of events more natural. Events are such things as developings and growings; they are flashes and bangs, they are movements of things, they are sneezings, collidings, touchings, breakings, buildings, and so on.

We thus have two very different approaches to the question of causation that are based on opposed metaphysical frameworks. It is the second of these that, we argue, is the more natural one for biology, with its need for continuity. The two frameworks, in summary form, are as follows.

(p.72) *A. Static relatedness*: The world consists of a succession of static events, as in perdurantism, and then some of those events are 'connected' together by a contingent relation. That relation might be regular succession, counterfactual dependence, probability raising, or something else. Causation is the (unobservable) relation the might hold between some of the static relata; hence the two-event-plus-relation model. Similarly, causal powers are understood according to a conditional analysis that, again, analyses them in terms of a relation holding between events. There are thus no irreducible causal powers in the sense required by the dispositionalist.

> This framework is essentially Humean in origin and fits an event/fact ontology. It dispenses with active, powerful particulars and is favoured by empiricist modern philosophy, which is suspicious of strongly modal connections between distinct events. All of Aristotle's four causes are dropped from the account except for efficient causation, which is also given a reductive analysis. Many of the presuppositions are retained even in contemporary anti-Humeanism, simply by making the connection between the causal relata necessary rather than contingent. But this is still merely connecting static parts in an attempt to manufacture change. This model starts with changelessness and then tries to construct change.
>
> *B. Dynamism*: Change is everywhere. It is continuous, in the sense that it does not break down into changeless parts. Causation begins as soon as certain processes are appropriately aligned, which is to say that they form a mutual manifestation partnership with respect to some effect. When they are so aligned, a new process begins and continues dynamically (always in a state of change) until it reaches its end (exhausts itself) or is interrupted, either additively or subtractively.
>
> This framework is roughly Aristotelian in origin, since change is fundamental in the Aristotelian tradition; but it is less committed to substances and more to processes. We can fit the account with Aristotle's four causes in the following way. Particular bearers of powers—*material causes*—can be constructions out of such processes, where what we think of as a single substance is a temporally extended process or a set of processes. Ultimately, it is not that a thing is a subject of change: a thing is constituted by a set of interrelated changes. We can think of a matchstick as an example of material causes, which are bearers of powers. Powers, such as flammability, are akin to the *formal causes*. The *efficient causes* are

the so-called stimulus conditions, which we have accounted for here as the coming into being of a mutual manifestation partnership: the striking of the match against a rough surface, for example. The *final cause* is the manifestation type towards which a power is directed—in this case, burning—which gets there through a process of combustion. This final cause is still to be found in any abstracted segment of that process in that the struck match is always directed towards burning until it reaches that end.

Space and time will usually be thought of as dense within this framework, which means that between any two times or places there will always be a third. Space and time will therefore be infinitely divisible. This in itself makes causes and effects connected (Bennett 1974) rather than merely conjoined, as Humeans would have it. If one opted for a discrete view of space–time, then there would always be a gap or a discontinuity between cause and effect, which would always be non-overlapping and temporally separated—something that Hume insists upon. With nothing bridging **(p.73)** that gap, it might then seem reasonable to think of causation as nothing more than regular sucession, for instance. With dense space–time, however, Bennett argues that cause and effect can literally be connected, namely through a process in which there are no gaps.

Our concern here has not been directly with the persistence of particulars (on this question, see chapters 1, 2, 4, 5, 6, 7, and 18); but the issue is relevant to our two frameworks simply because perdurantism posits the patchwork of changeless particulars out of which change is constructed. We have argued that a dynamic theory of causation ought to reject such a view. A powerful consideration remains that all the abstracted parts—the segments—of a process remain essential to it on the dispositional view we have outlined. In contrast, it is largely an accidental matter in perdurantism that a temporal part belongs to one particular process rather than another, given that such accounts almost always take the relations between parts to be contingent. As argued, however, on the dispositional view, a process has to go through a particular change or complex of multiple changes in order for it to be the process that it is, and this will be true of all natural causal processes. On the mosaic view, as is clear in Lewis's (1986c: ix) work, it is not essential to any piece of the mosaic that it be situated within the picture it is. All causal and nomic relations will be purely contingent.

5. Conclusions

We do not claim that the arguments above constitute a proof in favour of either a dynamic theory of causation or the dispositional variant of it that we prefer. Proofs are rare in metaphysics and philosophy generally. What we have done, however, is advance some considerations that ought be taken into account when selecting the best theory of causation. We have argued that the features of causation found in biology, and not just the features of inanimate causation found in physics, ought to be accommodated. In biology we are confronted with a multilayered complexity, which involves a number of overlapping processes that may all be essential for a proper causal explanation of particular phenomena. This is brushed over in many versions of the standard account, with its two-event model. We have also emphasized the dynamism found in biology, where organisms have to be constantly in motion in order to survive. This, we argued, does not sit well with an ontology in which there is a succession of changeless parts, no matter how those parts are stitched together through some form of relation. A theory of causation suitable to biology must emphasize continuity and connectedness. We added some detail to this, explaining how causes can be temporally extended, but also simultaneous with their effects, and nevertheless also be able to form causal chains of a longer duration.

There are other process theories available. Fair (1979), Salmon (1984: 147), Dowe (2000) and Kistler (2006) all offer alternative theories of causation. However, these are physically reductionist accounts in terms of a transfer of a conserved quantity or some other physical mark. Our account has no such commitment to reductionism, for reasons we cannot detail here (but see Mumford and Anjum 2011: ch. 4). We have been concerned with finding an account of causation fit not just for physics but for the living world as well. We have offered what we think is a plausible dispositional account.

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