Processes and Prediction
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What determines whether an object falls within the extension of a kind-predicate is the set of causal relations it can enter into. Similarity of possible causal relations determines similarity of kind-predication. Furthermore, one kind-predicate is distinguished from another by *dis*similarity of possible causal relations. Now, as mentioned in a previous chapter, Ned Block states at the close of "Anti-Reductionism Slaps Back" that since kind-hood is relative and graded, kinds are not the "key to causation" (Block 1997, 129). Indeed, Block is probably right. But causation might be the key to kinds. In what follows, I explore this possibility in light of a particular process theory of causation, and then I sketch a metaphysical picture based on my conclusions and propose a direction for further empirical research.

The layout of the present chapter goes as follows. In the first section, I introduce the notion of causal processes by looking first at Wesley Salmon's causal process theory (Salmon 1998) and then at some difficulties Salmon's theory faces. I turn in the second section to Phil Dowe's CQ theory (Dowe 2000). Although CQ theory is able to account for difficulties faced by Salmon's theory, it faces challenges of its own (Schaffer 2003). To avoid these challenges, I propose in the third section what I call 'micro-quantities theory' ('MQ theory'). Since kind-predication is guided by causation, MQ theory presumably can tell us something about kind-predicates and genuine kinds, should such things exist. I conclude in the final section that kinds do exist, but only at the micro level. I turn now to Salmon's theory of causal processes.

1. Salmon's Causal Processes

In his "Causality: Production and Propagation," Wesley Salmon argues that processes rather than events should be taken as the basic kind of causal relata (Salmon 1998, 285-301). Roughly put, causal processes are objects and waves that persist through time (Salmon 1998, 286). In order to differentiate between genuine causal processes and pseudo-processes, Salmon introduces the notion of a mark (Salmon 1998, 197). A mark is a modification in a process, such that if it is made at point *A* and continues to a second point *B* without either interruption or additional intervention, then and only then is the process said to transmit the mark (Salmon 1998, 197). Only those processes that are capable of transmitting a mark are causal; all others are pseudo-processes (Salmon 1998, 287). Salmon provides the following example: Suppose that a spotlight hangs in the center of a large round room with white walls such that when the lamp is flipped on a white beam of light travels from the lamp and forms a round spot on the wall. That the light traveling from the lamp to the wall is a causal process can be shown by the introduction of a piece of red cellophane to the light beam at some point between the lamp and the wall. The cellophane creates a mark by modifying the color of the light at the point at which the cellophane is introduced; and after that point, the light remains red without interruption and without the aid of additional intervention and thus the spot on the wall is now red.

The spot itself, though, is an example of a pseudo-process. Suppose that the spotlight suspended in the middle of the round room is rotated so that the spot of light runs along the wall. Furthermore, suppose that the red cellophane is held stationary about halfway between the lamp and the wall, so that as the spotlight is rotated, its beam will at some point pass through the red cellophane. Thus, as the spot travels along the wall, it remains white until it moves behind the red cellophane, at which point the spot becomes red. Once the spot moves out from behind the cellophane, however, it loses its modification and becomes white again. The spot's inability to maintain its redness after moving out from behind the cellophane indicates that the spot is a pseudo-process. Had the spot been a causal-process, then it would have remained red after it moved out from behind the cellophane. Now, even if the person holding the red cellophane were to wait until the spot on the wall became red and then run alongside the spot thereby keeping it red, the spot on the wall would fail to be a causal process. For, the modification is maintained only by continuous intervention. So, a process is causal iff it is capable of transmitting a mark from one point to the next without continued intervention.[1]

Phil Dowe objects, however, that some pseudo-processes are not excluded by the mark criterion. The most compelling counterexample Dowe puts forward is one in which the pseudo-process of a car's shadow seems to meet the mark criterion sufficient to call it a causal process (Dowe 2000, 74-9). Suppose that a car is parked such that its shadow is cast upon a nearby standing fence (Dowe 2000, 79). If the fence were to fall over, then the shadow would be modified by a single interaction (the fence's falling), and the shadow would maintain this modification. Surely, though a shadow is not itself a causal process. In order to obviate this sort of counterexample, Salmon adds a counterfactual criterion,

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[1]Importantly, a process needs only to be capable of transmitting a mark in order to qualify as a causal process; it need not actually transmit mark.

according to which a causal-process would have remained unaltered *ceteris paribus* had the marking interaction not occurred, but a pseudo-process would not have so remained (see Dowe 2000, 79). Rightly enough, though, Dowe responds that the shadow would have remained unaltered had the fence not fallen and furthermore was altered only in virtue of the fence's falling. Salmon's theory of mark transmission, it thus seems, fails to rule out such counterexamples (Dowe 2000, 79).

In the following section, I shall discuss Dowe's conserved quantity theory. First, I will offer a brief overview of the theory and show how it handles Dowe's own shadow objection to Salmon's mark criterion. Then, I will discuss two objections that have been raised by Jonathan Schaffer against Dowe's theory. Finally, I posit a modification to the conserved quantity theory that will allow it to deal with these objections.

2. Conserved Quantities Theory

In order to circumvent the difficulty faced by Salmon's causal theory, Dowe puts forward a process theory based upon the notion of conserved quantities. Dowe describes the conserved quantity (CQ) theory as consisting in the following two statements (Dowe 2000, 90):

> CQ1: A *causal process* is a world line of an object that possesses a conserved quantity.
>
> CQ2: A *causal interaction* is an intersection of world lines that involves exchange of a conserved quantity.

To explicate the first a bit, a world line is the history of an object as it is represented on a Minkowski diagram, and so a process itself is a spacetime "worm," *i.e.,* an object in fourdimensional spacetime (Dowe 2000, 90-1). Dowe includes within the extension of '*x* is an object' the objects of science (*e.g.*, particles, waves, and fields of force) and commonsense (*e.g.*, chairs, people, and spots; Dowe 2000, 91). Importantly, a spacewise gerrymandered thing counts as an object, but a timewise gerrymandered thing does not (Dowe 2000, 91). Consider for example, that the referent of '*x* is the President of the United States' is something that can be partially described thus (cf. Dowe 2000, 100):

for $t_{30\text{ Apr }1789} \leq t < t_{4\text{ Mar }1797}$	*x* is George Washington
for $t_{4\text{ Mar }1797} \leq t < t_{4\text{ Mar }1801}$	*x* is John Adams
for $t_{4\text{ Mar }1801} \leq t < t_{4\text{ Mar }1809}$	*x* is Thomas Jefferson

The variable '*x*' denotes a timewise gerrymandered thing that consists in a conserved quantity, but which fails to be an object in the CQ theory. *A*, however, is a spacewise gerrymandered and thus counts as an object:

$A =^{df}$ {George W. Bush, Miles Davis's trumpet, Manny the cat}

I argue below that the allowance of spacewise gerrymandered objects creates unnecessary difficulties.

Turning to the notion of a causal interaction, according to Dowe, an intersection occurs between two or more processes that "overlap" in spacetime (Dowe 2000, 91). Furthermore, by 'exchange' Dowe means the occurrence of a change in the value of the conserved quantity within at least one process, such that the change takes place at the point at which the world lines putatively overlap (Dowe 2000, 92). Finally, by 'conserved quantity' Dowe means any quantity, such as mass-energy and charge, that is subject to a conservation law, and Dowe maintains that at present the best guide to what these laws are is scientific theory (Dowe 2000, 91). So, on the CQ theory, causation is what occurs when the world lines of at least two objects interact such that a conserved quantity of at least one object changes at the point of the interaction.

Dowe then is able to avoid the objection he raises against Salmon's conception of causation. For, regardless of whether the shadow would have remained unaltered had the fence not fallen, the shadow itself does not consist in a conserved quantity; it "consists" in the absence of a quantity.

Jonathan Schaffer, however, raises two important objections against Dowe's theory: the so-called disconnection and mis-connection objections (Schaffer 2003). The disconnection objection points out that causation is often attributed to instances in which there is no direct connection between the cause and the effect and thus no single process connects two events. Consider the following example, given by Schaffer (Shaffer 2003). Pam, a devious young woman, desires to smash a neighbor's window with a brick. Instead of throwing it, however, she builds a catapult capable of launching the brick. After wheeling the catapult to the proper location, Pam cocks the catapult's arm, places a brick in the basket at the end of the arm, and then she raises the catapult's catch, thereby allowing the arm to swing free and the brick to be tossed. Pam's aim is perfect, and the brick shatters the glass.

In describing this scenario, one typically would say that the brick's shattering the glass was caused by Pam's releasing the catch mechanism on the catapult; after all, had Pam not raised the catch, then the window would presumably have remained intact. Consider, though, that there is a causal flow (a sequence of causal processes and causal interactions) that extends from Pam's raising the catch and the catch going up; however, the catch's going up is where the causal flow seems to stop. That is, what seems to have caused the window to break was the brick; what caused the brick to break the window was the brick's being launched by the catapult; and what caused the launch to take place was the *absence* of the catch. Thus, the flow from Pam to the window is disconnected.

According to Schaffer, the most plausible reply to the disconnection objection is to deny that the putative counterexample presents a case of genuine causation (Schaffer 2003). This reply entails denying that all commonsense attributions of causation are correct, for again commonsense tells us that Pam's having released the catch is what caused the brick to break the window. To put my cards on the table, I think the rejection of the scenario as a genuine case of causation is the right move to make, but for reasons given in the next section.

The mis-connection objection shows that not all conserved quantities involved in causal interactions are causally related to an end result. This objection, which Schaffer also expresses via a counterexample, seems more difficult for the CQ theorist (Schaffer 2003). Suppose that instead of catapulting a brick through her neighbor's window, Pam simply throws it. Shortly after Pam releases the brick, Tom, who is standing nearby, throws purple paint at the brick while it is in mid-flight. Like Pam's aim, Tom's is exact, and thus the paint strikes the brick, and the brick then smashes the window. In this case, there is a causal flow that extends from Tom to the broken window, but it seems inappropriate to say that Tom had a causal role in the window's being broken. Thus, while the paint is a genuine process extending from Tom to the window, it is not causal.

Schaffer describes two possible replies. The first is to admit that there are instances of causation that seem counterintuitive, although these instances are so negligible that they can be safely discarded (Schaffer 2003). So, in terms of the above counterexample, Tom in fact did play a causal role, albeit a minor one, in the breaking of the window. The second reply, according to Schaffer, is to recognize that multiple processes are often involved shaping a particular instance of causation (Schaffer 2003). I shall consider each of these possible replies in the next section.

3. Micro-Quantities Theory

Both the mis-connection and disconnection objections can be avoided by simply limiting what one is willing to count as an object. Since Dowe allows both objects in the ontology of science and the objects of commonsense to count, there are two directions the limitation can go: either eliminate commonsense objects by reducing them to the objects within the ontology of science or get rid of the objects of scientific ontology altogether. The former, which eventually results in what I shall call 'micro-quantities' ('MQ') theory, is the better route and can be achieved by viewing macro-level objects as *derivatives of* micro-level objects that are "bonded" together.

Consider that there are two ways to describe the scenario in which Pam throws her brick through the window and Tom throws purple paint on the brick as it is in mid-flight. According to commonsense, the brick and the paint comprise two distinct objects. Both objects have conserved quantities, and both of those quantities interact with the window. Consider furthermore that had Tom failed to throw paint, but Pam threw the brick (and the brick keeps the same trajectory across scenarios), the brick presumably would have broken the window. If, on the other hand, no bricks were thrown, but Tom simply threw purple paint at the window, then the window would not have broken. So, commonsensically, what breaks the window is only one object, *viz.,* a paint-splattered brick, and therefore taking paint to be a nominal cause of the window's breaking seems worse than merely counterintuitive. We have very good reasons to think that flying paint (except perhaps in controlled laboratory settings) does not break windows: paint thrown by a human simply does not have the requisite mass and velocity to accomplish the task.

The force of the misconnection counterexample derives from this seeming (mathematical) incongruity: commonsense tells us that there are two causal processes leading up to the broken window, but only one process was involved in the window's breaking. The difficulty, I think, is that commonsense is rarely rigorous enough to describe what is going on. According to the commonsense description, an object (a handful of paint) at one time *becomes* a property (denoted, '*x* is paint-splattered') at a later time. The paint-splattered brick is just the sort of spatially-gerrymandered object that Dowe seems to allow. This is not a terrible thing, for if push comes to shove the commonsense view can reply to the question, What is the causal role played by the paint? Answer: it caused the brick and (assuming the paint has not dried by the time the brick reaches the window) the bits of glass to be purple. So, the ontology of commonsense is fine for an everyday heuristic. It is not, however, fine-grained enough capture the nuances of causation in the world. So, one would do well to avoid commonsense ontology.

For this reason the MQ theorist rules out any gerrymandered objects whatsoever. Furthermore, non-gerrymandered (spacewise or timewise) object-hood should be viewed as existing in degrees, for macro-level objects are derived from aggregates of the micro-level objects found within the ontology of science (specifically particles, waves, and fields of the force should they prove to have quantity). 'Aggregate' should be understood roughly in the sense in which physics and chemistry speaks of particles "bonding." So, for example, a macro-level square peg counts as an object (though derivative), because it consists of a set of particles bonded together at the micro-level; similarly a drop of water counts as a macro-level (and thus derivative) object. Two adjacent but unattached bricks, however, are not bonded at the macro-level and thus do not together form a single object, derivative or otherwise.

Two felicitous things follow from this move. The first is a measurement issue: if macro-level objects are understood as aggregates of micro-level objects, macro-level quantities will be seen as having been "built up" from micro-level quantities. This is beneficial, for exchanges of conserved quantities can be described in greater detail.

Second, if macro-level objects are seen as aggregates of micro-level objects, the processes of conserved quantities can be "followed" with a greater degree of accuracy to their points of interaction with other processes. Such fine-grained descriptions of processes allow the MQ theorist to avoid criticisms arising from what might be called macro-level "fission" and "fusion" cases of causation. A fission case exists when a single macro-level object is the common cause of, say, two effects. By admitting only micro-level particles, one need only to specify which particles interacted with which other particles to bring about the two macro-level effects. That is, by homing in on the micro-level process, one can follow the conserved micro-quantities to their points of interaction and can thus give a more accurate description of causal occurrences.

A macro-level fusion case occurs when three or more macro-level processes converge, but only two macro-level processes seem at the macro level to have causally interacted. The paint and the brick case is an example of a macro-level fusion case. The paint-splattered brick is comprised of two previous aggregates of particles that at some later point come to comprise a single aggregate of particles. Since macro-level objects are derivative, this forms no problem. So, in this way, by admitting only micro-level objects as the primary objects, the MQ theorist avoids the mis-connection objection.

Finally, the disconnection objection, as exemplified by the catapult, can also be avoided by appealing to micro-level processes. At the micro-level it is quite obvious that there are multiple causal processes interacting with the catch standing at the nexus. First, a causal interaction occurs between Pam and the catch when Pam uses the catch to lock the catapult's arm in place just before the launch.[2] Second, the catch's holding the catapult's arm in place before the launch is both *(a)* a causal interaction between the catch and the catapult's arm and *(b)* a background *condition* for the causal interaction between the catapult's arm and the brick. Finally, the catapult's arm interacts with the brick, and then the brick interacts with the window. Background conditions allow for the possibility of other causal interactions, and it is here that the break occurs in the causal flow from

[2]For simplicity of description, I shall set aside Pam's interaction with the catapult's arm and will focus only on Pam's interaction with the catch.

Pam to the window. A causal interaction occurs only between Pam's fingers and the catch, and a distinct causal flow runs from the catch, to the arm of the catapult, to the brick, and then to the window. So, Pam's connection to the broken window is only indirect; she merely establishes the background conditions for the causal interactions between the catapult's arm and the brick, and the brick and the window. This is most easily seen by considering the various causal sequences of processes and interactions at the micro level.

So, by limiting objects to only the micro-level objects in the ontology of science, causation can be cashed out in terms of micro-level processes, which accords with Schaffer's second proposed response. By taking causation to consist in micro-level processes, the roles multiple micro-processes have in an instances of causation become obvious. Now, I consider the notion of kinds and kind-predicates in light of MQ theory.

4. Conserving Kinds

So far, I have argued for a specific causal process theory. First, I presented Wesley Salmon's notion of causation as a process which is capable of transmitting a "mark." Phil Dowe, however, has put forward several counterexamples to Salmon's concept, one of which proves quite difficult for Salmon's theory. Therefore, I took up Dowe's theory according to which causation is an interaction between two causal processes in which an exchange of quantities occurs. Schaffer, however, has presented two counterexamples to Dowe's CQ theory. In the last section above, I proposed a means for coping with Schaffer's criticisms. The solution is to take as genuine objects (and thus as causal processes) only those objects (processes) that occur at the micro level; macro-level objects (processes) are therefore seen as derivative. This move, which results in what I call the 'MQ theory' of causation, avoids Schaffer's criticisms and reveals something important about the universe: if MQ theory is right, then it shows that causation occurs only at the micro level.

Now, it has been assumed throughout this thesis that whether or not an object falls within the extension of a kind-predicate is determined largely by the causal relations it can enter into. In fact, it is not just any causal relations, but certain relations as determined by the Disney Cluster of an object. Therefore, kind-predication is guided by causation. So, if MQ theory is right, it might have something to say about kind-predication. In fact, I think it does.

Before discussing the notion of kinds and kind-predicates, however, it will be useful to clarify further the notions of objects and object-hood which is at play in MQ theory. Given the argument in the last section, micro-level particles are basic ontological entities, for these are the objects whose processes enter into causal interactions. I take it, therefore, that Locke is in a sense right to say that an object x at t_1 is the same as an object y at t_2 iff "no addition or subtraction of matter" occurs to the object (Locke 1948, 163). Only, I would go one step further: in order for an object to retain its identity through time, it must be nomologically impossible for the object to add or lose parts. Consequently, the only non-derivative objects there are, are micro-level particles which can have such properties as positive or negative charge, spin, and so on.

As stated somewhat loosely in the last sections, derivative objects consist in aggregates of these particles. The Ship of Theseus, for example, is thus a derivative object. Once a single plank (or a single particle, for that matter) has been removed, the aggregate of particles ceases to be the same, and the derivative object is therefore different. Supposing that the plank-replacing activity occurred on the sea and that a crew sailing on a different ship behind the Ship of Theseus collected all of the lumber, nails, etc. and put it all back together in the same arrangement as before, then (assuming also that no particles were lost while each board floated on the waters) the original aggregate of particles would have been restored, and thus the original derivative object would have existed with the second crew. The intuition that the first ship retains the label 'Ship of Theseus' despite every bit of its wood having been replaced arises largely from the fact that humans operate at the macro level and thus expect the world to, as well. If MQ theory is right, however, causation occurs at the micro level and thus what determines whether two macro-level objects are identical is the identity of the micro-level particles that comprise them.

A consequence of MQ theory is that macro-level kind-predicates are attributed to derivative objects, *viz.,* macro-level objects consisting in aggregates of particles. In fact, I take it that a macro-level object consists ontologically in *nothing more* than its micro-level constituents, for I do not know what sorts of things could be added to an aggregate of micro-level particles to make it a macro-level object. I thus take it that emergentism is false; the properties of wholes are nothing more than the properties of the micro-level parts and their relations to each other. So, what distinguishes the micro level from the macro level seems to be mere macro-level observation. Furthermore, observers at the macro level are incapable of perceiving differences at the micro level between, say, two objects without the aid of scientific instruments. But if those two objects are different at the micro level and objects in general are *ontologically* nothing over and above their micro-level constituents, then their macro-level similarities are *merely apparent*. So, insisting that two objects are both members of the same kind because they appear at the macro level to be similar and then claiming that macro-level kinds are nonreducible is logically akin to saying that chairs, cars, and tennis balls belong to a kind which is nonreducible. Of course it is nonreducible, the constituents have nothing to do with each other.

Now, of course the reader will cry foul, for kind-predications are not made merely on the basis of macro-level similarity. Rather, they are made on the basis of a similarity of how objects partition the set of causal relations. Chairs, cars, and tennis balls are not even close to partitioning the set of causal relations in the same way. My perhaps radical, but (it is hoped) eventually plausible claim is this: neither are two tigers.

Consider this: First, again, macro-level objects, presumably, are ontologically nothing over and above their micro-level constituents. Second, kind-predicates, as mentioned above, are applied in light of the causal relations an object can enter into. In fact, two objects are given the same kind-predicate iff they partition the set of causal relations similarly. Third, also as shown above, causation itself seems best explicated in terms of processes at the micro-level. Since causal relations occur at the micro level and similarity of causal relations must therefore occur the micro level, kind-hood, if it is a genuine feature of the world, also must exist at the micro level.

So, drawing from MQ theory and the explication of object-hood given above, the genuine kinds of the universe are plausibly the fundamental processes of the universe, *viz.,* particles with similar internal properties and waves with similar functions (and perhaps fields of force if they turn out to possess quantities). On this view, then, two particles with negative charge fall within the same kind, two waves with the same function fall within the same kind, and so on. All else is built up from and thus are derivatives of these kinds.

The pertinent question is this: Can the relatively few number of kinds in the universe account for the deep scientific similarity that seems to divide derived objects into the extensions of respective special-science kind-predicates? Perhaps so. If the number of protons in an atomic aggregate is two less than the number of electrons, the aggregate as a whole will be (derivatively) negatively charged. Given that two atoms are exactly similar with regard to quantities of protons, neutrons, and electrons, the two atoms will behave quite (though perhaps not exactly) similarly. As an initial speculation, however, I think the limited number of genuine kinds is insufficient to account for the similarities observed in the special sciences. What else is needed is the notion of statistical significance. As one works one's way up through the hierarchy of special sciences, raw similarity becomes more obscured. Statistical methods must be employed to bring out any underlying similarities.

Regardless, MQ theory is able to account for causation in a way that avoids the difficulties faced by Salmon's mark theory and Dowe's CQ theory by reducing object-hood to the micro-level. Furthermore, since causation guides kind-predication, MQ theory accords well with attempts to reduce special kinds to lower-level kinds. The analysis of special predicates in the third chapter of this thesis combined with MQ theory provides a parsimonious metaphysical framework worthy of further consideration. If my arguments turn out to be sound, then all that lies at the nexus of causal processes and kind-predication is physics of the most fundamental kind.

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