Causes and Laws: The Asymmetry Puzzle

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How are causes and laws related? Some attempt to analyze causal relations in terms of laws, others view causal explanation as quite distinct from explanation using laws. My analysis of the relations between causes and laws focuses on cases such as the simple pendulum law where asymmetries in causal relations between quantities are not reflected in the functional dependencies in the law equations. The asymmetry puzzle has elicited a variety of accounts which reflect quite different views on the relation between causes and laws and their roles in scientific explanation. Finding none of the usual accounts satisfying, I offer an explication based on some distinctions in the analysis of the relevant causes that are not commonly heeded. I criticize the very notion of causal law and examine some implications of my account for *ceteris paribus* problems which arise in attempts to give realist interpretations of scientific theories.

1. The Pendulum and Other Puzzles

The simple pendulum is a paradigm example used to show a gap between laws and causes. The law for a simple pendulum is expressed by the equation: $T = 2\pi\sqrt{L/g}$ where T is the period, L is the length, and g the gravitation constant. Using the law, we can calculate the length L given the period T as well as the period given the length. Why then can we only cause the period to change by changing the length, not cause a change in the length by changing the period? Is there information left out of the equations, beyond operational interpretations of the measures of the L and T variables? Where does the additional causal information, if any, reside? What implications does the asymmetry of the causal relations as opposed to lawful relations have for the use of the law in scientific explanation?

Examples like that of the pendulum law suggest the following simple argument to show that causal relations are not "in" the laws: There is typically no asymmetry in the dependence of quantity variables in the the equations expressing the laws. But the causal relations are asymmetric. Therefore, the causal relations are not represented in the equations.

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The pendulum puzzle is not an isolated problem. The contrast between causal relations as opposed to functional dependency among quantities can be made for many laws. Consider Ohm's law: V = IR (voltage is the product of current and resistance). We can change the current flowing by changing the voltage, but we cannot change the. resistance by changing the current or voltage. Using the law, we can deduce the value of resistance R given the values of current I and voltage V, but we cannot say that a resistor has value R because the circuit has current I and voltage V. In Newton's second law we can change the acceleration by changing the force or the mass but we cannot change the mass by changing the acceleration or the force (aside from relativistic effects outside the scope of Newton's laws). Similarly, we can change the force of gravitation between two bodies by changing the masses, but we cannot change the masses by changing the distance.

Though the asymmetry question arises for many laws, it is not uniform over what Hempel (1965, p. 352) labeled laws of coexistence. For the case of the ideal gas law: PV = NRT, it seems that we can cause a change in any of the variables— pressure, temperature or volume—by changing the other variables. For example, it sounds correct to say that raising the temperature may cause an increase in the pressure or volume, and by changing P or V we can change T. As I shall argue, however, what we should say is that whatever means we use to raise the *temperature* of the system, *that* is what causes an increase in pressure, say, at constant volume.

We can imagine systems in which the length of the pendulum is indeed changed by its oscillating so that an increase in the period does explain an increase in the length. If a pendulum made of highly elastic substance, the centrifugal force generated by the swinging of the pendulum could increase the length from what it was when not oscillating. In such a case the period has an effect on the length. But this is different from applying a force in addition to gravity to change the period, which would not, in a simple pendulum system, tend to change the length. Similarly, increase in current can cause an increase in resistance by raising the temperature of the resistor, but this effect lies outside the scope of Ohm's law.

2. Previous Accounts of the Asymmetry

Reactions to the fact that causal relations are apparently not captured in the representation of the law by the equation vary widely. Two general kinds of answer have been proposed corresponding to two accounts of the locus of the asymmetry. According to one view there is really nothing of objective significance missing in the laws. A second view is that the functional representation of the law is incomplete as a basis for real (causal) explanation.

Of course, if there is no role for the concept "cause" in science, questions about the source of causal asymmetries have no bearing on scientific explanation. If we accepted Russell's notorious claim that "the reason why physics has ceased to look for causes is that, in fact, there are no such things" (1917, p.174) the asymmetry problems must simply arise from the vagaries of nonscientific notions of causation. A similar view, which also sees no objective information missing in the functional law,holds that causal relations merely express differences we impose.The direction of causal relations on this view corresponds to a distinction of dependent as opposed to independent variables in our use of laws, so that the asymmetries depend on what we select as important, say for our purposes of control. There are then no objective asymmetric dependencies among quantities which fail to be expressed in the law equations.

Instead of simply banishing causes from science, Carnap reconstructed the concept: "within science, causality means nothing but a functional dependency of a certain sort" (1928, p.264). Realizing that "nobody would want to call a momentary state a 'cause'", he concluded that his scientific causes "exist only in refined reconstructions of physics". On this construal of causes the asymmetry could be seen as arising not from something missing in the laws but rather from incompleteness of the common expression of causes. Moving to the complete set of sufficient conditions (Mill's "philosophical cause") would restore the symmetry of lawful relations. If causal relations reduce to lawful relations, or at least if the cognitive content of statements of causal relations can be reconstructed in terms of laws, whatever is scientifically relevant about causes is really "in" the law equations.

A prominent use of the asymmetry problem has been to show inadequacies of the Deductive Nomological model of scientific explanation. In a classic critique of the DN model, Bromberger (1966, p.83) offers an account for "certain asymmetries that have puzzled some philosophers" (1966, p.83). His example of a flagpole casting a shadow has been much discussed. The height of the pole and the length of the shadow can be calculated symmetrically, one from the other, using geometrical relations. But we can only say that the height of the flagpole explains the length of the shadow, not that the shadow's length explains the pole's height.

I shall focus on examples such as the pendulum which involve what are more commonly considered natural laws. Concerning the pendulum example, Bromberger notes that a statement of the period of oscillation of a pendulum is not an answer to the question: "Why is the length of the string at the end of which the bob is hanging so many inches long?" His explication is that "the asymmetry is traceable ...to the fact that whereas the period would not have been what it is if the length had not been what it is, the length would have been what it is whether the bob had been oscillating or not" (p. 83). In this account Bromberger in effect translates the puzzle into a question of the truth of counterfactual statements about the period and length of the pendulum. I want to inquire what underlies the truth of the counterfactuals, agreeing with van Fraassen (1980) that causal intuitions are more basic in this case than our understanding of context sensitive counterfactuals. van Fraassen's own discussion of explanatory asymmetries, however, only contributes to his conclusion that explanations are relative to contexts. Contextual aspects of explanations do not, however, reveal the relations between causes and laws which, I shall argue, do account for the asymmetries.

Citing the pendulum law, Cummins argues that the "causal character of standard subsumptive explanations is obscured by the equational form of most physical laws" (1983, p. 2). Derivation of the value of the period from the law, given the value of the length, is explanatory, but derivation of value of length given the value of the period is nonexplanatory. Cummins places the blame for the asymmetry puzzle on Humean regularity accounts of causality. Regularity accounts try to reduce causation to lawful connection: to be causally connected is just to be an instance of a nomological generality. Since no asymmetry is expressed in the pendulum law equation, the causal asymmetry must rest on a "prior conviction that changes in length cause changes in period and not vice versa" (p.3). Against a pragmatic account, Cummins notes that talk of what we can control as introducing the asymmetry simply reverts back to what causes what. He goes on to distinguish "transition theories" which use causal laws to explain changes from "property theories" which explain instantiation of magnitudes of quantities. This distinction is quite right and important, though I shall argue that the very notion of causal laws supposed to be involved in transition theories is not clear.

To account for the explanation asymmetries Salmon appeals to the obvious fact that "we explain events on the basis of antecedent causes, not on the basis of subsequent effects (or other subsequent conditions)" (1984, p.95). One has just to see what causal process is involved. In the case of Bromberger's flagpole "the light from the sun must either pass or be blocked by the flagpole *before* it reaches the ground where the shadow is cast." Salmon goes on to analyze the flagpole example in terms of his statistical relevance model of explanation. Of all the accounts I find Salmon's the most illuminating, though it does not bring out fully the relations between interaction causes and laws which I see underlying the asymmetries.

3. Interaction Causes and Determining Conditions

To account for the causal asymmetry of period and length of a pendulum as opposed to symmetry within the law requires distinguishing interaction causes from lawlike determining conditions. While we cannot say that the period of the pendulum causes the length to change we can say: that the period of a simple pendulum has value T is, *ceteris paribus* a sufficient condition, for the length having value L. The intuitive idea of interaction causes is expressed by Sellars when he notes that"causation in the ordinary sense is the idea of the intervention of an agent in a system, thereby bringing about changes which would not otherwise have occurred" (1966, p.142). Citing an interaction cause singles out a source of an effect. The determination of one quantity in a law by others is a rather different concept. Against Margenau's claim that what "A causes B" means in physics is that 'A' and 'B' designate total states of a theoretically isolated system where A occurs at an earlier time" (1950, p.395) Ducasse responded that Margenau "cannot be talking about the causation involved when we say something is bent, pushed, ignited or scratched by another thing" (1969, p.151) Ducasse refers here to interaction causes as opposed to Margenau's state conditions of a system. (Note that Ducasse here "slips" into talk of causes as relating "things", which in scientific contexts might be construed as systems.) Yet he seems to lose sight of interaction causes when he analyzes our usual sense of "cause" as "the one concrete change immediately preceding" the effect event. Such a cause seems in effect to be the total state of the region surrounding the effect event.

Rather than attempting here to give a full analysis of causal interaction as opposed to lawful determination, I will simply mark the contrasts most relevant to the asymmetry problem.[1] The most crucial difference between what I call interaction causes as opposed to determining conditions expressed in laws is that the conditions apply within a system whereas interaction causes are external to the system on which they operate. The importance of this elementary distinction in understanding physical theories, particularly in thermodynamics and quantum physics, is recognized in scientific work but not always given much attention in general discussions of causes and laws.

The account of causal relations in Salmon (1984) makes the insightful move away from standard analyses of causal relations in terms of conditions to a consideration of the concepts of causal propagation and production. I find Salmon's scheme of analysis cogent with the exception of a complaint about the way he characterizes causal interaction. He sees causal interaction as constituted by an intersection of two processes which "undergo correlated modifications that persist after the intersection" (p.170). Salmon uses the term 'process' to refer not only to, say, a lightwave propagating through space but to material things persisting through time, such as a molecule or a bacterium. I suggest that we follow the intuitive grammar in which the subject of the verb 'interact' represents an individual or object rather than, as most commonly, an occurring event. Instead of saying, with Salmon, that a modification in one process is produced by an event "consisting in the intersection of two processes" I suggest we say that a system A (as a localized object) interacts with a system B to cause a change in B if there exists a causal process originating from A that changes system B. Causal relations then, in what I take as the basic interactive, productive sense, involve three components, as in Salmon's analysis (1980, p.156) with one change: what constitutes the cause is not an event but a substantive source, a system external to the system exhibiting the effect event, and with a causal process connecting the two systems. The difference in terminology brings out an asymmetry in the relata of causal relations which is important in some contexts.

The conception of an interaction cause as a relation between one system as source of a change in another system actually fits some of Salmon's own examples better than construing causes as events. When he cites the bacterium which "causes the disease" in an explanation of the Great Plague I find it hard to conceive of this as an event (for Salmon the bacterium is a "process"). In examples of common causes (p.160), citing the poisonous mushrooms as the source, the common cause of simultaneous illness, makes more sense than the event of eating the mushrooms. In the case of the twin quasar image, it makes more sense to cite the single luminous body which emits radiation in two slightly different directions rather than the event or process of emission.

When discussing explanation by causes and by laws we need to distinguish "explaining why" in terms of conditions as opposed to "specifying what" in ascribing a cause of a change. An interaction cause is a source of interference that is necessary-in-the-circumstances and external to the system in which the effect event takes place. When we ask for the cause of a change within a given system with respect to the parts of the system, we consider the system as made up of interacting subsystems. A causal interaction on a system requires that the system change its state from what it would have been had there been no physical influence, a transfer of mass/energy which violates the isolation of the system. In this light I interpret Cummins (1983) "transition theories" as serving to analyze relations of states of a system into interaction relations among its constituents. In contrast to a transition theory, the gas law is a case of a "property theory" since it "explains temperature in a gas by explaining how temperature is instantiated in a gas" but it does not by itself explain changes in temperature (p.15). Cummins notes that we know much about what causes pain (I would say: we know interaction causes) but not how it is instantiated (determination in a system).

4. Source of the Asymmetries

The asymmetry puzzle for the pendulum arises from the way the system is defined. Laws apply to kinds of model systems, for example the ideal gas law to ideal gas systems. The systems, model objects, are the domains over which the variables in a functionally expressed law range. The pendulum bob is an object we characterize independently of its role in the pendulum system, independent of the period. To change its length requires a change in the pendulum bob as a physical object. The length of a pendulum must first be fixed before the pendulum as a well-defined physical object can have a period. The value of the length is a property of state of the system which determines the value of the period. Conditions of the system can only be changed by interaction causes which change properties of the system. We can change the length as a property of a component object of the system, but we cannot construe the period as an instantaneous property of any object in the system. The period is a property of an event (the oscillation of the bob), which is an effect of the earth's gravitational force acting on the pendulum object. We cannot change the period, *qua* effect of gravity operating on the bob, without first changing its determining condition, the length.

In order to formulate a general explication of asymmetry cases, consider the case of Ohm's law. The resistor, a wire say, is an object which we characterize independently of its role in the electric circuit system, independent of the current or voltage. To change the resistance value R of the resistor wire requires (relative to Ohm's law) a change in the physical object. The current flowing can be viewed as a sequence of event effects of the voltage acting on the wire whereas the resistance is a capacity of the resistor object that is independent of the current flow.

There is nothing pragmatic about the asymmetries. They do not depend on how we view the variables according to our interests, once the systems are defined. Nor is the asymmetry something left out of the law, implicit in the interpretation of the law or in a *ceteris paribus* clause needed for application of the law. Nor is the pendulum law an abstraction from causal facts that make it true (as, for example, suggested in Cummins' account). The causes are "external" to the law. Interaction causes may change the properties which are related in the law but such properties of the system do not correspond to any interaction causes at all. The pendulum law entails that were there a change ΔL in length in the model system, there would be a change of ΔT in the period. This would require an external cause of the change in length L. So when we say that changing the length causes a change in the period, we should say more precisely: if some interaction cause changes the length L, the new length L* determines a new period T* so long as the system remains a simple pendulum system. We can also cause a change in period T (exert force on it). But this does not determine L according to the pendulum law since we no longer have a simple pendulum system.

In general, if an interfering cause changes the state of a system such that the effect on the system is a change in a variable (say T for pendulum system), then the other state variables change as required by the law (provided the system remains a model to which the law is applicable). The point is that the law applies to the effects of the interaction, not to the interaction causes themselves. If we want to explain why an interaction cause S_1 caused event e in S_2, we look to laws relating relevant properties describing S_1 to properties of S_2.

5. Against Causal Laws

Some accounts of explanatory asymmetries require appeal to causal laws as opposed to laws of association. Reference to "causal laws" is common, but there are rather different conceptions of them. I prefer to say there is no such thing as a causal law. This is not because I have anything against causes or against laws but because none of the usual natural laws have causes "in" them. I think Lindsay and Margenau were quite correct to claim that "physics knows of no law connecting cause and effect" though wrong to conclude that "concepts [of cause and effect] are foreign to physical analysis" (1936, p.517). They recommend simply speaking of boundary conditions and initial and final states of a system. Conditions, however, apply to states of one system. To bring in causes requires the concept of interaction causes upon systems. Unlike Russell's causes, interaction causes do play roles in science but not in laws. Of course, one can define a sense of the label "causal law" but what are generally called causal laws are either not "causal" or not laws. Margenau and Carnap, we noted, view process laws as causal because they define proper physical causes as relations between states of a system.

Davidson (1967) proposed a weak form of the regularity theory of causation. Instead of demanding that a singular causal statement be subsumable under some known law, he requires only that the causal statement entail the existence of some covering law. The covering law is supposed to be a causal law which subsumes the singular causal statement. The schema he suggests for causal laws is:

$$\text{(S)}\ (e)(n)[(Fe\ \&\ t(e) = n \rightarrow (E!f)(Gf\ \&\ t(f) = n + \varepsilon\ \&\ C(e,f)],$$

where 'e' and 'f' are individual event variables, t(e) is a function assigning numbers as a measure of time, and 'C' represents the relation between a given cause and its effect (p.699). To get causes into causal laws, Davidson simply introduces a causal relation into the law. This not only undercuts the Humean point of the regularity analysis but it is difficult to interpret for examples of causal claims. Cummins (1983, p.193) actually formulates a causal form of the pendulum law, with a causal relation Cee* in it. Cee* reads: change in length e causes change in period e*. But is it the process of changing from one length to another or the fact that the length has changed that causes the changing of the period? The fact that the length changed does indeed determine a change in the period according to the pendulum law. But the event of change in the length of the bob could occur a long time interval before the pendulum is set back in motion. In such a case we would not want to call the *event* of changing the length a cause of the change in period. I suggest that what we should refer to as a cause of a change in the pendulum system is some interaction cause.

Haugeland (1983) contends that no fundamental laws are causal since the variables range over physical magnitudes, not causes and effects. He is right in noting that it "makes no sense" to say in the context of the ideal law that a pressure change occurs first, then causes temperature change or vice versa.[2] But his conclusion that "causality is fundamentally a nonscientific ”folk“ concept" (p. 66) is quite wrong. Causal interactions as distinct from nomic determination are as objective as anything in science and indeed are required in the most developed scientific theories, for example, in the interaction concept of causal signals in relativity theory and interaction measuring devices on systems in quantum physics.

My conception of interaction causes requires a restatement of even Davidson's weak nomological principle of causality, that a singular causal claim entails the existence of a law subsuming the cause and effect events under some description. I contend that we can only say that if e causes f, then there exist laws (not in general a single law) which may be probabilistic, where a description of e instantiates the antecedents and description of f instantiates consequents of the laws. The Humean empiricist requirement that the concept of a cause is logically tied to the generality of laws reflects what Salmon calls the "epistemic" as opposed to an "ontic" analysis of causal relations (1984, p. 16). In epistemic analyses, warrants for causal relations are taken to be analyses of what causes are. If we speak of causal laws as governing causal interactions (as Salmon 1984, p. 132), we should note that the laws are "causal" only contextually, not that being causal is a property of the law itself.

Cartwright (1983) sees causal laws as the only ones which are ever true. But her examples are not what are typically called laws of nature: "Smoking causes lung cancer." — "Perspiration attracts wood ticks." — "Spraying with defoliant causes death in plants." — "Uranium causes radioactivity." These are regularities of a sort but they relate material kinds rather than properties or magnitudes of quantities. I would rephase those not citing material kinds as causes. Although we say (and most philosophers prefer to say) "smoking causes lung cancer" it is not the act of smoking but the smoke which is carcinogenic, just as it is the perspiration, not the act of perspiring that attracts wood ticks; and the defoliant, not the act of spraying it that plants to die. I read these as interaction causes, sources of effects. The almost universal prejudice against "thing" or "substance" causes may reflect a desire to reject animistic and final causes, to legitimize causes by subsumption under laws. I wouldn't call Cartwright's paradigms of "causal laws" laws because there do not seem to be any theoretically uniform states underlying the causal capacities in question. The conditions for unity of a law are different from those for interaction causes. Essential to laws on any account is generality. Interaction causes are particular and may not be subsumable under a single law.

In passing from verbal expressions of a law to a functional representation, the causal talk with implicit reference to interacting systems drops out. Faraday's expression of the law of electromagnetic induction, for example, was: "the electromotive force induced in a current loop is directly proportional to the rate at which the magnetic field lines are cut" (Longair 1984, p. 39). Here there is implicit mention of something which cuts the lines. Some years later the law was put into mathematical form as $E = - d\Phi/dt$. The EMF is expressed here as a function of the rate of change of the total magnetic flux through the circuit, with no reference to interaction causes.

6. *Ceteris Paribus* Qualifications

One approach to the asymmetry problem is to view functional representations of laws as elliptical. Perhaps we should look to *ceteris paribus* conditions as necessary for real causal explanations. One might say then that the causal relations are really in the laws when these are fully expressed. In formulating laws we consider model systems isolated from external influences, from interaction causes. We may say then that a law applies to a particular real system provided there are no interfering forces. A *ceteris paribus* qualification that there are no interfering forces is best construed, I suggest, as a requirement on the definition of the model systems over which the variables of the law range and to which the law is supposed to apply exactly rather than as qualifications on the application of the law to real phenomena approximating the model systems.[3] Thus we can distinguish exact laws for ideal systems from approximate laws for real systems.

In Cartwright's recent work on Nature's Capacities (1989) I see suggestions of the way certain *ceteris paribus* qualifications might better be construed. This does, however, require changes in terminology which may do violence to her perspective. She sees causal relations, based on background knowledge, as breaking the "symmetric interpretation" of equations in econometric theory so that the structural equations themselves can be interpreted causally. Certain parameters in laws are distinguished in that they "represent causal capacities" Cartwright characterizes the intuitive notion of a capacity as "a causal power that a system possesses by virtue of having certain property or being in a certain state" (p. 190). I suggest interpreting the "capacities" here as interaction causes. Cartwright cites as a paradigm analogy a functional correlation relation of pressure on a gas throttle of an auto with a corresponding maximum speed of the car. This is a noncausal determination relation which allows symmetric calculation of pressure and speed. Such functional correlations contrast with structural relations which reveal inner mechanisms of the auto engine. I see the shift to inner mechanisms as introducing interaction causes among constituents rather than requiring causal powers ascribable to states of the system.

Cartwright's conception of separation of variables according to causal components can be used in clarifying the roles of *ceteris paribus* clauses for laws. Consider her example of the demand law equation: $q = ap + u$ which relates quantity q demanded as a function of price p (and random shock factor u). The coefficient of demand, a, represents the price's capacity to produce or inhibit demand. Why is this capacity treated as "autonomous"? Because, I suggest, it is a capacity of a kind of thing *qua* that kind of thing independently of determination of variables in the system of the demand/price relations. This is analogous to viewing resistance as a capacity of the resistor qua material object, the wire say, as opposed to a property determined by relations in the circuit system. Hausman (1989) notes that demand functions provide cases of causal asymmetry: "in the context of consumer choice theory, demand depends on price not(baring Rube Goldberg set-up) vice versus" (p.313). Although price is a property of an object in a more complex way than resistance is a property of a resistor, I think the causal intuitions are similar.

The kinds of idealizations involved in *ceteris paribus* clauses which function as presuppositions of the interpretation of laws fall into three general classes:

1. Choice of the domain of systems isolated from interfering causes.

2. Fit of the model object as an approximation to a real system. This question arises after defining the domain of model systems to which a law applies and is an idealization within the system. The bob of a pendulum, for example, is treated as a point mass in deriving the simple pendulum law.

3. Mathematical approximations in deriving the law for an ideal system. This might be called approximation of the model structure in contrast with idealizations of the model object.[4] For example, in deriving the pendulum law using gravitational force and Newton's laws, the accurate differential equation for the idealized pendulum is not solvable analytically. To get the simple pendulum law the approximation is introduced that for small angles of swing $\sin 0 \approx 0$.

4. Conclusion

My analysis of the asymmetry puzzles has led me to separates sharply laws from causes, from what I consider the most causal of causes, interaction causes. Interaction causes are only remotely related to laws. In justifying the ascription of an interaction cause as the source of change of a system we might try to subsume aspects of the causal process under laws. But I rejected even the weak empiricist maxim that to know causes is to know the existence of a law. The general implication for realist interpretations of theories is that the question of getting true laws is quite distinct from the question whether theoretical entities are real, for the latter question is tied to questions of real causes. The issue whether theoretical laws are true is the question whether they represent structures in real systems. However that may be, laws do not provide grounds for ascribing reality to purported entities corresponding to theoretical terms appearing in the laws. With causal efficacy as a mark of reality, following Hacking's maxim on the reality of positrons "if you can spray them then they are real" (1983, p.23), a realist should look not to the role of theoretical entities in laws but rather to their role as interaction causes.

Notes

[1] In Byerly 1979, I gave an analysis of what I called "substantial causes", which correspond to what I call here interaction causes. The label 'substantial' may be misleading.

[2] I do not believe Haugeland's particular argument here is cogent, however. He argues that temperature and pressure of a gas for fixed density are "different manifesta-

tions of a single underlying average". But pressure depends on average momentum, temperature on mean kinetic energy of the particles.

[3] This is clearer on the semantic view of interpretation of theories, one of its advantages over the classic syntactic interpretation.

[4] For a discussion of the distinction between model structures and model objects, see Byerly 1969.

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