Chapter 14
Causation Across Levels, Constitution, and Constraint

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14.1 Introduction: Scientific Explanation and Causal Explanation

According to the traditional conception of logical empiricism, all scientific explanations are causal explanations. The deductive-nomological analysis was intended to indicate at the same time what it takes to be a scientific explanation and what it takes to be related as cause and effect. However, it is well known[1] that there are explanations that satisfy the formal requirements of the DN analysis without intuitively being causal: in such explanations, the initial conditions do not appear to refer to a cause of the explanandum. Additional requirements need to be imposed on two facts or events in order for them to be related as cause and effect, requirements that may be alternative or additional to the requirement of playing the logical roles of initial condition and conclusion in a valid DN-argument. One important suggestion is that causation requires the existence of a mechanism linking the cause to the effect. Such a mechanistic conception of causation falls into the wider category of process conceptions of causation according to which: (1) causes and effects are essentially localised in space and time, in other words they are events, and (2) the causal relation between such events is based on a local, intrinsic process the end points of which are the cause and the effect.

14.2 Reducing Causation to Mechanism?

No doubt, mechanistic explanations are causal explanations. It is part of what it means to be a mechanism that it extends from an initial to an end condition, where the former causes the latter. It is clear that initial and end conditions are meant to

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[1] See, e.g., Humphreys (1989, p. 300/1), Salmon (1990, pp. 46–50) and Kistler (2002).

M. Suárez et al. (eds.), *EPSA Philosophical Issues in the Sciences: Launch of the European Philosophy of Science Association*,
DOI 10.1007/978-90-481-3252-2_14,

bear on different moments in time. Hence there can be no question of a "mechanism" linking two aspects of the same event. As a consequence, a mechanistic analysis avoids the wrong prediction of the DN analysis, that there may be causal relations between different properties of one substance at one time, such as between the temperature and the pressure of a given sample of gas.

But some have made the stronger claim that the concept of causation can be reduced to that of mechanism. According to Stuart Glennan, "events are causally related when there is a mechanism that connects them" (Glennan 1996, p. 49). Glennan himself admits that such a mechanistic account of causation "cannot explain causation in fundamental physics" (Glennan 1996, p. 50). It cannot be true of interactions between elementary particles that the existence of a causal relation is equivalent to the existence of a mechanism. Glennan concludes that there are two fundamentally different kinds of causation and suggests that "there should be a dichotomy in our understanding of causation between the case of fundamental physics and that of other sciences." (Glennan 1996, p. 50).

However, one would need stronger reasons to justify the radical and counterintuitive conclusion that there are two distinct concepts of causation, one for fundamental physical interactions and one for all other causal relations. This consequence is avoided as soon as one abandons the idea that causation can be *reduced* to mechanism. On closer inspection, it appears that the concept of mechanism presupposes that of causation, far from being reducible to it. Providing a mechanistic explanation means to decompose the working of a complex system into a number of simpler subsystems that interact causally with each other. These subsystems can in general themselves be analysed in still simpler subsystems, so that the interactions between the former subsystems can also be mechanistically explained. The crucial point is that each step of the analysis of a mechanism makes essential use of the notion of cause, and thus presupposes it. If one pushes the analysis far enough, one eventually reaches interactions between elementary particles. These however cannot in their turn be given a mechanistic analysis, because elementary particles cannot be decomposed into their parts. It follows that the concept of mechanism cannot be used to analyse the concept of causation and that, quite on the contrary, the concept of causation is among the irreducible conceptual instruments of mechanistic analysis. Mechanist causation rests in the last instance on the causation of fundamental physical processes.

14.3 "Top-Down" and "Bottom-Up" Experiments

Even if the concept of mechanism does not provide the means to reduce the concept of causation, reflection on the mechanistic analysis of complex systems and their experimental investigation may help us answer a major question raised in recent philosophical work on causation. Scientific experiments on mechanisms seem to rely on causal processes crossing the boundary between levels of composition, both in upward and downward direction.

- In "bottom-up" experiments, one manipulates properties ("independent variables") of individual components of a mechanism in order to observe the consequences of this intervention at the level of system properties ("dependent variables"), i.e., properties belonging only to the whole mechanism but to none of its parts.
- In downward or "top-down" experiments, the experimental intervention consists in manipulating system properties and observing its effects on properties of components of the mechanism.

An important category of bottom-up experiments uses the so-called "knockout" technique: organisms are genetically modified in such a way that specific genes are deleted. The observation of the development and behavioural capacities of such animals is taken to license inferences about the causal contribution of the knocked out genes to the development and capacities of the animal.

If there is bottom-up causation, we may expect there also to be top-down causation where a cause consisting in the modification of system properties has effects at the level of the system's microscopic constituents. Indeed, some experimental strategies seem to presuppose its possibility. In techniques of brain-imaging such as fMRI (functional magnetic resonance imaging) and single-cell recording, the experimenter manipulates system properties, e.g., by putting animals in a situation in which they accomplish a specific behavioural task, and observes subsequent modifications of properties at lower levels: fRMI allows to measure nervous activity in specific brain regions; single cell recording allows to observe the activity of individual neurons.[2] Such experiments intervene causally at the level of the organism: one manipulates the behaviour of the whole animal. The measured effect of that intervention lies at the level of the animal's microscopic constituents: one observes modifications of the properties and activities of neurons in the hippocampus.

Are such "interlevel" experiments instances of top-down and bottom-up causation, which means that they are grounded on interlevel causal relations? Scientists' statements suggest an affirmative answer. In Eric Kandel's words, the "biological analysis of learning requires the establishment of a causal relation between specific molecules and learning" (Kandel 2000, p. 1268). More specifically, Kandel acknowledges the existence of downward causation: "Learning produces changes in the effectiveness of neural connections" (p. 1275). Downward causation also seems to be required to make sense of psychotherapy: "Insofar as social intervention works [. . .] [e.g.] through psychotherapy [. . .] it must work by acting on the brain" (*ibid.*).

Recent philosophical work on causation also seems to lead to acknowledge bottom-up and top-down causation. According to Woodward (2003), causation can be analysed in terms of manipulability. If a cause of some property or factor E is a factor C such that interventions on C allow to manipulate E, then the bottom-up and top-down manipulations undertaken to understand the working of mechanisms are all cases of causation.

[2] See Ludvig et al. (2001).

14.4 The Puzzle of Downward Causation

However, downward causation, through which the evolution of a complex system causally influences the evolution of its own parts, raises considerable conceptual difficulties. Kim (1998) argues that downward causation is conceptually incompatible with two plausible metaphysical principles. The first, suggested by the success of physics in explaining physical phenomena, is the principle of the "causal closure of the domain of physical phenomena". It says that for a given physical event e that takes place at time t, for each time t^* preceding t, there is a complete physical cause c (at t^*) of e.[3]

The second principle used in Kim's argument is that there is no systematic overdetermination of microscopic events by independent micro- and macroscopic events. If event e at t has a complete physical cause c at time t^* (where t^* is earlier than t), then it does not (at least not in the general case) in addition have another complete cause C at the same time t^*, which is independent of c. In particular, if e is a neural event happening in a subject's brain at t, and c is a complete cause of e at the neural level, there will not (at least not in each case) be other complete causes of e that are simultaneous with c; in particular, there will not be a complete cause C at the cognitive level that is independent of c.

Here I can only sketch the argument against the conceivability of downward causation that Kim develops on the basis of these principles.[4] It proceeds in two steps. In the first step, Kim shows that the only way a mental event C could cause a second mental event E, is indirect, by causing, through a process of downward causation, e, the physical basis of E. By causing e, C necessarily brings about E, because e is E's supervenience basis. The supervenience relation entails that every instance of e is necessarily an instance of E. In a second step, Kim argues against the possibility of downward causation, which would, according to the first step, be required for mental causation. Given the causal closure of the physical domain, e has, at the time of C, a complete physical cause c. Now, either C is supervenient on c, in which case C is not an independent cause from c, or C is independent from c, in the sense that one could occur without the other. Then C's causing e is a case of overdetermination of an event, e, by two independent causes, c and C. It is controversial whether overdetermination is possible in exceptional cases, but it is generally taken for granted that it is implausible to suppose that all mental causes are cases of independent overdetermination.[5]

[3] Cf. Kim (1998, p. 37/8). See also Lowe (2000a, 2000b, p. 26 ff.).

[4] I have analysed Kim's argument in more detail in Kistler (2005, 1999/2006a, 2006b).

[5] It has been argued, e.g. by Mills (1996) and Walden (2001), that the effects of mental causes are systematically overdetermined by mental and physical causes, and that this overdetermination is not the result of the dependency of the mental causes on the physical causes. Mills makes it clear that "causal overdetermination requires the *distinct, independent* causal sufficiency of P [a physical cause] and of my believing" (Mills 1996, p. 107; italics Mills'). For lack of space, I cannot here examine Mills' and Walden's arguments in detail. Let me just note that Mills' own justification for the causal efficacy of a certain belief, with respect to the fact that his arm raises, contradicts this claim of independence. He justifies it by the truth of a counterfactual according to which

Kim's argument puts us before a dilemma: Either the argument is sound and we must revise our interpretation of interlevel manipulation of complex systems, so that it does not require any downward causation after all, or we abandon one of the two metaphysical principles Kim uses in his argument, so as to open up the logical space for downward causation.

14.5 Analysing Interlevel Causation in Terms of Constitution

Let me begin by the metaphysical notion of constitution, which is used to distinguish a material object from (1) its matter and (2) the set of its parts. In the present context, constitution is used to refer to the latter: the relation between a macroscopic object and the set of its parts. I will use Unger's (1980) example of the relation between a cloud and the droplets it contains, but the same points could be made with any other macroscopic object, such as tables, chairs and living beings. Here are two reasons why the set of tiny drops in a given cloud is not identical with the cloud: first, considering the evolution of the cloud in time, the concept of cloud allows it to persist, i.e., to continue to exist and remain the same cloud, while individual drops enter or leave it. However, each time a drop is added or removed, the set of drops in the cloud changes. Moreover, and this is the second reason for distinguishing the cloud from the set of its drops, even at a given moment of time, it would have been *possible* that the very same cloud contains some more drops or some less. Let us admit Kripke's thesis that all true identity statements of form "A = B", where A and B are rigid designators, are *necessarily* true. It follows from the contrapositive of this thesis that if a statement attributes a contingent relation to A and B, that relation cannot be identity. The fact that there could have been a different set of drops in the cloud, shows that the relation between the set of drops and the cloud is contingent. Therefore it cannot be a relation of identity. Here is where constitution steps in: One can say that the actual set of drops constitutes the cloud although they are not identical.

Three features of constitution will prove important in what follows. First, it is an asymmetric relation: if A constitutes B, it is impossible that B constitutes A. The set of drops constitutes the cloud but the cloud doesn't constitute the set of drops. Second, a given object can be, successively or alternatively, constituted by more than one set of parts. One might express this by saying that some objects allow for "multiple constitution". Third, constitution is a relation of logical and metaphysical, rather than epistemic or nomological type. It is not epistemic because the fact that a given set of drops constitutes the cloud is independent of our knowing or ignoring

the belief causes the arm movement in a possible world in which its physical cause is absent. Now, this counterfactual is true only because "worlds in which my belief is accompanied by some physical event that causes the arm-raising preserve actual laws, whereas worlds in which my belief is unaccompanied by any such physical event do not" (Mills 1996, p. 109). This reasoning seems to presuppose that there is a nomic correlation between physical and mental properties, which contradicts their independence.

this fact. The way in which we justify claims of constitution shows that they are not nomological. Hypotheses bearing on laws of nature can only be justified a posteriori, on the basis of observations of facts that are logically independent of each other and of those laws themselves. However, if I know the position and speed of each drop in the cloud, I know and can infer on purely conceptual grounds all properties of the cloud, such as its position, form and density. Therefore, the objects described by the premise (the drops) and the conclusion (the cloud) stand in a logical or metaphysical, rather than a nomological, relation.

Let us now turn to Craver and Bechtel's analysis of apparent cases of downward causation. Take their example of the process that begins with a person's decision to start a tennis game and leads to appropriate tennis-playing behaviour. The latter requires a raise of glucose consumption in the person's muscle cells. The decision, a system property of the person, seems to have effects at the cellular and molecular levels. However, Craver and Bechtel argue that this appearance is misleading, and disappears at closer inspection. "The case can be described without remainder by appeal only to intra-level causes and to constitutive relations" (Craver and Bechtel 2007, p. 559). If this is correct, downward causation can be analysed according to one of two patterns. In scenario 1, C (the decision) determines c (the brain state underlying the decision), which then causes e (enhanced consumption of glucose in muscle cells) by intra-level causation.

In scenario 2, C (the decision) causes E (appropriate behaviour at the level of the organism), which then determines e (enhanced glucose consumption) in a non-causal way.

The first scenario is inadequate if, as is generally assumed, mental events such as decisions to play tennis are multirealisable by many different brain states. Which particular brain state c realises C depends on the person's history and the circumstances. At any rate, C does not by itself determine c. Furthermore, even if it did (in other words, if we abstract away from multiple realisation), the downward determination of a brain event by a mental event could not possibly be construed as a relation of constitution, because constitution is a bottom-up relation.

The same reasons seem to make scenario 2 inadequate: First, E does not in itself determine e because tennis-playing behaviour, and even a given detailed bodily move, can be realised at the molecular level in many ways. Second, E does not constitute e: Parts can be constitutive of wholes but wholes cannot be constitutive of their parts.

14.6 Downward Causation and Downward Constraints

However, it is possible to reinterpret scenario 2 in such a way that it may represent the situation correctly. I suggest modifying Craver and Bechtel's proposal in two respects. First, the downward relation by which E determines e is a relation of *constraint* not of constitution. Second, the constraint imposed on e by E is not complete but partial.

Let me say a few words on the notion of constraint. A constraint limits the possibilities of evolution or change accessible to a system. In a system of equations with n variables, each equation imposes a constraint on the variables, in the sense of limiting the values the variables can take to satisfy the equations. If the variables represent the degrees of freedom of a physical system, i.e., the dimensions within which the state of the system can evolve, the notion of constraint acquires a physical meaning. Each equation expressing a link between the variables expresses a limit imposed on the possibilities of evolution of the system. Each constraint on a macroscopic system diminishes the number of possible states of its constituents. However, as long as there are less constraints than degrees of freedom, the constraints on a system determine its state only partially and not completely.

Contrary to constitution, constraint is not an asymmetric relation. One can say that the state of the parts of a system constrains the state of the whole; but it can also be correct to say that the state of the whole constrains the states of the parts, as when the position of a solid limits the degrees of freedom of the atoms constituting it.

The notion of degree of freedom, and thus the notion of a constraint limiting those degrees of freedom, can be generalized to all determinable properties of a system that can take different values. An animal's body temperature corresponds to a degree of freedom subject to the constraint of remaining within limits imposed by a regulatory mechanism at the level of the organism. However, this temperature constitutes itself a constraint imposed on the possible states of motion of the molecules composing the organism. The overall temperature imposed on the body by the regulatory mechanism limits the space of possible states of motion of the body's constitutive molecules, by fixing the mean kinetic energy of their states of motion. In the same sense, the fact that a given cognitive system is at a given moment in some cognitive state, e.g., of consciously perceiving an approaching tennis ball, imposes a constraint on the possible states of its parts, and first of all on the state of its neurons. It is incompatible with many neuronal states, such as states corresponding to closed eyes or the contemplation of an immobile scene. However, it is only partial and compatible with a great many microscopic states of neurons and molecules.

The process leading from the decision (C) of a person to her playing tennis (E) is an intra-level causal process at the level of the organism. I suggest that the concept of *partial constraint* helps us understand the relation between tennis playing and the underlying microscopic events e taking place in the body, such as enhanced glucose uptake in muscle cells. The state of organism E exerts a constraint on its parts, in the sense that the fact that the organism is in state E limits the space of possible states of its muscle cells. However, the detailed evolution of each muscle cell is also constrained at the cellular and molecular level, by the physical state of the cell and its surrounding.

The notions of constitution and constraint, which are both forms of non-causal determination, make causal relations crossing levels of composition conceivable. It is after all conceptually possible that a change occurring at the level of the parts of a system causes changes at the level of its systemic properties, and that a change of systemic properties causally influences the states of its parts.

With this analysis in mind, let us return to Kim's argument against the possibility of downward causation. According to Kim, the idea that a change in system properties might exercise a causal influence on the properties of the system's parts is incompatible with the principles of the causal closure of the physical domain and of explanatory exclusion. The controversial premise is the principle of the causal closure of the physical domain. Downward causation is possible if there can be microscopic events in complex systems that are not completely determined, in the long run, by same-level events. Cellular or molecular changes in a living organism may, e.g., not be completely determined over long time intervals by other cellular or molecular events. The brain may exhibit "deterministic chaos".[6] The possibility to make predictions about the evolution of a chaotic system is limited to a short time span. In other words, one cannot (deductively) explain a molecular event in a living organism (such as the transformation of an ATP in an ADP molecule in order to release the energy necessary for muscle contraction), on the basis of other molecular events that have occurred much earlier.

One can only draw a metaphysical conclusion – that the state e of the set of parts of the system at t is not causally determined by the state c of the set of parts of the system at t^* – from an epistemic premise – that it is impossible to make long term predictions in some chaotic systems – if one accepts the following two presuppositions. The first concerns the interpretation of the notion of causal determination. Causal relations can be analysed at two levels: they can be construed as relations between particular events, where a "particular" is a concrete object or event having many properties. At that level, it may be hypothesized that causation rests on the transmission of some quantity of energy (or some other conserved quantity) from one event to the other[7]. However, when one is interested in causal explanation, it is in general not sufficient to point to causal relations at the level of events in this sense. One does not only want to know which event made the billiard ball move at time t, but also what it is about the cause event that makes the effect event one in which the ball moves with a speed of 1 m/sec. In other words, the search for a causal explanation aims at establishing a *fact* about the cause event that is responsible for a fact about the effect event. What is causally responsible for the *fact* that the ball moves with 1 m/sec, is a fact bearing on the masses and speeds of the relevant billiard balls at some time earlier than t, say t^*. This "responsibility" of facts bearing on events happening at t^* for facts bearing on events happening at some later time t rests on laws linking the properties that are constitutive of those facts: laws link speeds and masses at t^* to speeds and masses at t. There is an ontological interpretation of this nomic determination: the dependence of the state of the billiard balls at t depends on their state at t^*, independently of our knowledge and description of

[6] Cf. Skarda and Freeman (1990), Lehnertz and Elger (2000) and Newman (2001).
[7] This thesis has been defended in Kistler (1998, 1999/2006a, 2006b).

these facts. In a realist framework, true deductive-nomological explanations of facts at t on the basis of facts at t^* have a truth-maker: the causal dependence, or causal responsibility of the latter for the former.

The second presupposition is that the indeterminacy of the state of a chaotic system is not only epistemic but also ontological. No empirical sense can be attached to the hypothesis that a determinable property of a physical system with a continuous value pattern, possesses at time t an absolutely precise value. There are absolute limits to the possible precision of measures that appear in the so-called uncertainty relations of quantum mechanics. Even if the state of a chaotic system has been determined with the absolutely maximal precision at time t^*, that state does not completely determine the state of the system at times t that are sufficiently distant from t^*. In such a chaotic system, the "horizontal" determination of physical events at the physical level is objectively incomplete. This throws doubt on the "principle of closure of the physical domain". In such a system, for a given physical fact at time t, and for times t^* sufficiently earlier than t, there is no physical fact at t^* that completely determines e. This does not mean that such a fact is completely indeterminate. The success of ethology and psychology in explaining numerous animal and human behaviours shows that animals and humans obey to "system laws"[8] constraining their evolution at the level of systemic properties, such as cognitive laws determining actions on the basis of reasoning and decision making. The fact that an organism obeys to such laws means that its evolution obeys constraints at a psychological level. The constraints exercised on the organism by laws at different levels, at the level of the organism as a whole and at various lower levels corresponding to its parts, create no conflict. If the determination of a molecular event is incomplete at its own level, it may nevertheless be completely determined jointly by laws at molecular and system levels. A given molecular event happening in an organism may be partly determined by constraints at the molecular level and partly by downward constraints from the psychological level, insofar as the organism obeys to psychological system laws[9].

The possibility of this scenario shows that, contrary to what Kim's first principle says, present-day scientific knowledge does not exclude the hypothesis that the domain of physical phenomena is not closed. The microphysical state of a complex system at t^* may not completely determine its microphysical state at a much later time t. In such a system, the microphysical state at t may be partially determined in a downward direction by the constraint that the system must, at t, be in a global state compatible with system level laws, such as cognitive laws. The determination of state e is completed by the physical circumstances occurring immediately before e.

[8] Cognitive laws linking actions to reasoning and decision are one case of what Schurz (2002) calls "system laws". Insofar as an organism exhibits regularities at the level of the organism, it is what Cartwright (1999) calls a "nomological machine".

[9] I have justified this sketch in a little more detail in Kistler (2006b).

14.7 Conclusion

Mechanisms are causal processes, and their analysis shows that they contain other more elementary causal processes. At the bottom level, there are fundamental physical causal processes that cannot, for lack of parts, themselves be given a mechanistic analysis. Therefore the concept of mechanism cannot be used to provide a noncircular analysis of the concept of causation.

Nevertheless, the analysis of mechanistic explanation can help us decide whether the mind can influence matter, and in particular, whether our decisions to behave can be considered as causes of microscopic changes in our body. Many philosophers take such "downward causation" to be mysterious and incompatible with general metaphysical principles abstracted away from science, such as the principle of the causal closure of the domain of physical events. I have tried to show that partial downward determination of microphysical states of a complex system is conceivable and does not violate any plausible scientific or metaphysical principles.[10]

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[10] I thank my auditors in Madrid and Reinaldo Bernal for helpful criticism and discussion.

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