Commentary

Scientific Explanation and the Causal Structure of the World

Wesley Salmon
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The time had come «to put the "cause" back into "because"» (Salmon, 1984, p. 96), and a theory of explanation had to be developed with an essentially *causal* character: it was together with his theory of explanation that Wesley Salmon developed a theory of probabilistic and mechanistic causation, outlined in detail in *Scientific Explanation and the Causal Structure of the World* (1984). His conception of causation aims to shed light on scientific explanation as a way to open the "black box of nature" and reveal its inner workings, and has ever since become a locus for anyone interested in dealing with causal explanation and putting forward a mechanistic notion of cause.

Salmon's reflections stem from an interest in explanation and from radical criticism of and a number of counterexamples – well-known in the literature – to the "received view" of explanation. That is where the volume starts. Salmon's Statistical-Relevance model (S-R), elaborated back in the early Seventies, is meant to overcome the limits of the Hempelian models, and, more specifically, the Inductive-Statistical model (I-S). The inferential form of explanation, the requirement of high inductive probability, the epistemic relativization of statistical explanation are strongly opposed, insofar as they are regarded as both inadequate to represent genuine explanations and implicitly committed to a deterministic view of the world. According to S-R, to explain an event is to identify all and only the factors that are statistically relevant to its occurrence, where a factor C is taken to be statistically relevant to the occurrence of an event B under circumstances A if and only if $P(B \mid A \cdot C) \neq P(B \mid A)$. The initial reference class is to be partitioned until a *homogeneous* reference class is obtained, i.e., a class that cannot be further partitioned by

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means of statistically relevant factors and does not include any irrelevant factor. The explanation is obtained by assigning the event to be explained to the appropriate final reference class.

While acknowledging epistemically and pragmatically homogeneous reference classes as well, Salmon's proposal is centered on the notion of *objectively* homogeneous classes, to warrant *genuine* statistical explanations, independent of the knowledge situation. The S-R model conveys explanatory information by providing relevant partitions and allowing prior and posterior probabilities to be compared. Statistical relevance, either positive or negative, is all is needed in this respect, with no requirement whatsoever on the final probability value of the event to be explained. All events, highly probable as well as highly improbable ones, can be explained in the very same way, within a perspective that, without committing itself exclusively to either a deterministic or an indeterministic view, is compatible with both. The rebuttal of Hempel's position is accompanied by the proposal of an *ontic* conception of scientific explanation, capable of placing the events into networks of objective relations. Opponent approaches are described: the epistemic conception (subdivided into inferential, information-theoretic and erotetic) and the modal; the epistemic conception is held to be grounded on nomic expectability, the modal conception on nomological necessity. Whereas these views are judged inadequate to deal with an indeterministic perspective and unable to grasp the difference between explanation and description, the ontic conception is claimed to fulfill both tasks.

Soon aware that explanatory relevance cannot amount to just statistical relevance, but must be traced back to causal relevance, Salmon commits himself to the elaboration of an objective concept of causation on empirical grounds. The S-R model is by no means eliminated, but comes to play the role of the first level in a two-tiered model of explanation which has causation at its core. The notion of causation intends to implement the S-R basis and unravel the network of productive links underlying phenomena, often operating in stochastic ways. A first decisive step in this direction is the proposal of a "process ontology", substituting the "entity ontology" characterizing other views of causation, such as Reichenbach's (by which – on the other hand – Salmon is largely inspired). The causal relationships that scientific explanation must capture are clarified by the notions of "causal process", "causal production" and "causal propagation". Instead of starting off with a single definition of mechanism, like other subsequent mechanistic accounts, Salmon builds up his theory piecemeal on these notions. Processes are defined as spatio-temporal continuous entities, such as waves and material objects persisting through time. Causal processes are distinguished from so-called pseudo-processes through the criterion of mark transmission: a causal process is a process which is able to transmit a mark, i.e., a modification of its structure, from the point in which it is imposed onwards without further interventions. Unlike pseudo-processes, causal processes can transmit information, energy, structure, and, in sum, causal influence. The causal network underpinning phenomena presents a conjunctive fork, where causal processes arise from a common cause and common background conditions, and interactive forks, where two causal processes directly intersect and produce mutual change. In the latter case, when two causal processes are both persistently modified in the interaction, causal production takes place, giving rise to statistical distributions of results. Causal influence is then propagated along causal processes, thanks to their spatiotemporal continuity. Propagation occurs according to the Russellian "*at-at*" theory of motion, according to which «to move from A to B is simply to occupy the intervening points at the intervening instants. It consists in being at particular points of space at corresponding moments» (Salmon, 1984, p. 153). Statistical relations provide hints of causal relations; causal processes, causal interactions, and the causal laws describing them provide the mechanisms by which the world works. The statistical-relevance and the causal-mechanical levels are regarded as equally crucial for the unravelling of the "causal structure of the world", and hence for an adequate account of scientific explanation. To explain a phenomenon is to locate it at some point within the net of causal processes: «these processes are the physical mechanisms that are responsible – probabilistically – for the phenomena we are trying to explain» (p. 123).

After the crisis of the notion of cause due to advances in XX century physics, Salmon was one of the leading proponents of its revival. His theory constituted a breakthrough in the debate on scientific explanation, providing a fundamental contribution to reflections on causation and explanation and emphasizing the distinction between *statistical causation* (corresponding to type causation) and *aleatory causation* (corresponding to token causation), both necessary for an adequate account of causation but conceptually distinct. Making his point more strongly, he later came to state:

> I believe that there is no such thing as probabilistic causality in the strict sense, because the probability relations require supplementation by such physical

> entities as processes and interactions. Reichenbach evidently regarded probabilistic structures and physical structures as distinct ways of approaching probabilistic causality. I believe that they need to be combined to yield a satisfactory concept of causality. I'd call it "physical (indeterministic) causality" rather than "probabilistic causality". (Salmon, 2010[1], p. 11)

In Salmon's view, a «satisfactory concept of causality» is reached by appealing to theoretical notions in the framework of an empiricist and realist perspective. A far-reaching debate was thus engaged with other authors, and especially with Bas van Fraassen, whose constructive empiricism and pragmatics of explanation he largely contrasts: «scientific experience provides strong support – Salmon holds – for the appeal to unobservable common causes and causal processes when observable domains do not furnish the required causal connections» (Salmon, 1984, p. 228). Consistently with his ontic view, he argues for the reality of unobservables, defended by appealing to the common cause principle and consistent results of different experiments (as, e.g., in the determination of Avogadro number by Jean Perrin in the early 1910s), and to a combination of causal and analogical reasoning (see Salmon, 1984, ch. 8).

Salmon intends to capture causation as it manifests itself contingently in our world. The counterfactual formulations of the criteria of mark transmission and causal interaction could thus constitute a threat to the empiricist approach he wants to embrace. A causal process is such that, *had* a modification of its structure *been performed*, it *would have transmitted* it from that point onwards; a causal interaction is such that, *had* two causal processes *intersected*, both their structures *would have been modified* from that point onwards. Salmon (1984) appeals to counterfactuals «with great philosophical regret» (1998, p. 18), and was glad to abandon them in the Nineties for Phil Dowe's "conserved-quantity theory" (see Dowe, 2000), which gets rid of counterfactuals. However, Salmon's intuitions on how to deal with counterfactuals are worth recalling, and constitute a – largely neglected – antecedent of some very recent views. In the last few years, both actual and *hypothetical* interventions have been increasingly recognized as playing a crucial part in the identification of mechanisms' components and functioning (e.g., Woodward, 2003; Glennan, 2002; Craver, 2007). The role of "interventionist counterfactuals" has been emphasized. The usefulness of counterfactuals to tell genuine causal relations from non-causal ones and the

[1] Published posthumously.

possibility of interpreting them experimentally were already pointed out by Salmon. He believes that science has a direct way of dealing with the kinds of counterfactual assertions required for causal assessments: the ability to transmit a mark and the property of being a causal interaction are assessed by performing certain kinds of experiments (see Salmon, 1984, pp. 147–149). This interpretation is presented as fully objective. Even though we often play an active role, «human agency plays no essential part in the characterization of causal processes or causal interactions» (1984, p. 174), given that they would be such even if no human agent were to perform the experiments. Hints towards the way in which both the interventionist and the neo-mechanist perspectives are currently incorporating counterfactuals can thus be found in the very place where the "anti-counterfactualist tradition" (Woodward, 2004) arose, namely in Salmon's probabilistic mechanicism and his conceptual apparatus as elaborated in the Eighties.

What about the applicability of Salmon's theory? Both in its original form and – even more – in the "conserved quantity" version, it has been criticized for not being widely applicable, and possibly adequate only with respect to physical and chemical causation. It has been accused of imposing too strong requirements (e.g., homogeneity and spatiotemporal continuity of processes), of providing just some sort of abstract geometrical network of processes and interactions, adaptable only to idealized or very simple cases, and lacking of indications on how to identify the explanatorily relevant causal processes and interactions. As a matter of fact, the examples provided in (1984) cover an extremely broad set of phenomena, of both a commonsensical, everyday sort, and strictly scientific. They range from bacterial infections to food intoxication, from radioactive decay to delinquency acts, from the collision of billiard balls to the presence of a worked bone in an archaeological site. When actual science is referred to, however, physics is no doubt what Salmon has mainly in mind, and this also strongly affects his attitude towards the relationship between general and singular causation, which is seen as unproblematic. While no disciplinary restriction is drawn, quantum physics remains highly puzzling for Salmon's view, which admittedly does not fit quantum phenomena (1984, pp. 247–259).

Whereas Salmon primarily questions *what* causal processes and interactions *are*, a major concern of neo-mechanists in the last decade has had to do with what mechanistic reasoning is *good for*, with a more in-depth focus on the disciplinary fields in which mechanist notions can be implemented, and the purposes for which mechanistic models are employed. Aiming at capturing the actual use of causal notions, and especially interested in such fields as biology, medicine, cognitive science, economics, the recent mechanistic approach stresses the dynamic character of mechanisms, and their being complex, multilevel structures, whose overall behaviour strongly relies on the internal organization of component parts and that can be structurally and/or functionally decomposable. These features do not play a part in Salmon's view, and this can be undoubtedly regarded as one of its main limits. Nevertheless, Salmon's view has been recognized as capable of grasping causation in some of the fields which are the very target of neo-mechanist views, such as biology and medicine (Schaffner, 1993), epidemiology (Vineis, 2000), economics (Mäki, 1992). What seems to be really missing in Salmon's account is a two-level example of scientific explanation starting from the very question of explanation and the identification of the initial reference class, through the relevant partitions and the homogeneous reference class, up to the relevant net of processes and interactions underlying the phenomenon to be explained. If in principle Salmon insists on the complementarity of the statistical and the causal level, no instance of the complete construction of a two-tiered explanation is provided.

While definitely advancing an ontic, objectivist perspective on causal explanation, Salmon's last chapter also recalls contextual aspects, especially by referring to Peter Railton's position, thus anticipating some of the latest trends. Most recent mechanistic literature emphasizes the relationship between the level of graininess of a mechanistic description and the context in which it is drawn, recognizes the possibility of elaborating mechanisms' sketches or schemas, and acknowledges that causal accounts exhibit some perspectival aspect. After starting mildly admitting of some context-dependent aspects of explanation in Salmon, 1984[2], Salmon soon afterwards (1989) came to suggest that a "new consensus" *with regard to scientific explanation* could eventually be built, which might show how the causal-mechanical, unificationist and pragmatic accounts could be compatible with and possibly complement each other. No consensus on scientific explanation has been reached, but Salmon's work both fruitfully casts light on how causation and explanation are intertwined and already presents many interesting hints towards what are now regarded as some of the crucial steps forward in dealing

[2] Remarks on contextual aspects will get bolder in Salmon (2002) and (2010).

with causation. Far from converging into some form of "consensus" of causation, such elements as the appeal to counterfactuals to be interpreted experimentally and some recognition of the role of the context are increasingly setting the ground for the interaction between different (both mechanistic and non-mechanistic) theories of causation, a trend the last Salmon might have been sympathetic with.

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