Mechanistic and Neo-mechanistic Accounts of Causation: How Salmon Already Got (Much of) It Right[*]

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Resumen

En la última década se ha presentado un número de teorías mecanicistas. Sin desmerecer los avances alcanzados en este tema, sostengo que el renacimiento mecanicista está más en deuda con Wesley Salmon de lo que se ha reconocido y que su trabajo ya hacía sugerencias sobre lo que hoy se consideran pasos cruciales hacia el tratamiento de la causalidad mecanicista. Más específicamente, sostengo que la teoría de Salmon ya señala, entre otras cosas, el papel crucial en el análisis de la causalidad de nociones como *producción*, *interacción y transmisión*; la compatibilidad de mecanicismo y propuestas *funcionales*; la distinción entre causalidad *constitutiva* y *etiológica* y, más importante con respecto al debate actual, la utilidad de *contrafácticos*, *interpretados experimentalmente*, como herramientas confiables para distinguir las relaciones causales genuinas de las no causales.

Palabras clave: causalidad mecanicista - teoría de Wesley Salmon - visiones neo-mecanicistas

Abstract

In the last decade or so a number of mechanistic theories have been put forward. Without denying the progress made on the topic and the many distinctive merits of neo-mechanistic views, I argue that the mechanistic revival is much more indebted to Wesley Salmon than has been recognized and claim that his works already offered important hints at what are now being regarded as the crucial steps forward in dealing with mechanistic causation. More specifically, I argue that Salmon's theory already pointed out –among other things– the crucial role in the analysis of mechanistic causation of such notions as *production*, *interaction* and *transmission*; the compatibility of mechanicism and *functional* claims; the distinction between *constitutive* and *etiological* aspects of causal explanation; and, most importantly with respect to the current debate, the usefulness of *counterfactuals, interpreted experimentally,* as reliable tools to distinguish genuine causal relations from non-causal ones.

Keywords: mechanistic causation - Wesley Salmon's theory - neo-mechanistic views

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1. Mechanisms and mechanistic explanations

In the last decade or so the mechanistic approach to causation has undergone a revival, with a number of mechanistic theories and varying definitions of *mechanism* being put forward. Among the most successful is that of Peter Machamer, Lindley Darden and Carl Craver (2000), according to which mechanisms are systems of entities and activities organized in such a way as to produce regular changes from initial to final conditions; Stuart Glennan (2002) claims that a mechanism is a complex system that produces a behaviour by the interaction of a number of parts, characterised by invariant, change-relating generalizations; and William Bechtel and Adele Abrahamsen (2005) maintain that a mechanism is a structure that performs a function by virtue of its component parts, their operations and organizations. Far from being incompatible, these views emphasize different aspects of mechanistic causation, can be partly compared and in some cases even combined, as suggested for instance by James Tabery (2004) through the notion of *interactivity*. Without denying that the large and burgeoning literature on mechanistic causation is tackling many important facets in original and promising ways, I argue that Wesley Salmon's contribution to the development of the mechanistic approach has not been properly acknowledged by the current debate, and show how his work already presents many interesting hints at what are now regarded as the crucial steps *forward* in dealing with mechanistic causation.

Moving from a deep interest in explanatison and strong criticisms of the Hempelian models, in the early seventies (1971), Salmon advanced the so-called *Statistical-Relevance* (S-R) model of explanation, according to which to explain an event is to identify *all* and *only* the factors 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 $P(B|A \times C) \neq P(B|A)$. The S-R model conveys information about statistical relevance relationships and aims to obtain *objectively homogeneous* reference classes –i.e. classes that cannot be further partitioned by means of statistically relevant factors and do not include any irrelevant factor– to warrant *genuine* statistical explanations, independent of the knowledge situation. The explanation is obtained by assigning the event to be explained to the appropriate final reference class; statistical relevance, either positive or negative, is all that is needed in this respect, with no restriction on the final probability value of the event to be explained: all events, be they highly probable or highly improbable, can be explained in the very same way.

Salmon soon realized, though, that genuine explanatory information has to be causal, and from the late seventies he elaborated his theory of causation, to implement the S-R model with a causal-mechanical level. To elaborate an adequate account of scientific explanation, Salmon believed that "the cause'" had to be put "back into 'because'" (Salmon 1977, p. 160), combining explanation with probabilistic causality. The S-R model is to figure as the first step, or the *basis*, of a *causal* account of explanation: "the relationships that exist in the world and provide the basis for scientific explanations are causal relations" (Salmon

1984, p. 121). Such relations are clarified by the notions of *causal process*, *causal production* and *causal propagation*, which lie at the heart of Salmon's theory as developed in the eighties. Instead of starting off with a single precise definition of mechanism, Salmon builds up his theory on these notions, which are neatly defined in various essays and volumes (see especially Salmos 1984, 1989, 1998). In brief, *causal processes* are continuous spatio-temporal entities which can transmit information, structure and causal influence; when two causal processes intersect and are both persistently modified in the interaction, *causal production* takes place. Causal influence is then *propagated* in a continuous way along the processes. Causal processes, causal interactions and causal laws are held to provide the mechanisms by which the world works. To explain *why* certain things happen we must see *how they are produced* by these mechanisms. The statistical-relevance and the causal-mechanical levels are regarded as equally crucial to unravel the "causal structure of the world", and hence provide an adequate account of scientific explanation. According to Salmon's theory of causal explanation, to explain a phenomenon is to locate it at some point within the net of, mostly probabilistic, causal processes: "these processes are the physical mechanisms that are responsible –probabilistically– for the phenomena we are trying to explain" (Salmon 1984, p. 123). Salmon wants to put forward an ontic conception of scientific explanation, capable of placing events in networks of objective relations and compatible with both a deterministic and, more significantly, an indeterministic conception of the world.

The view elaborated by Salmon in the eighties has been very successful, but also widely criticized. His theory of explanation has been accused of not providing a satisfactory account of causal relevance, and of drawing just a geometric, fairly abstract network of processes and interactions, able to represent only very simplified or ideal cases (see e.g. Hitchcock 1995, 1996, Woodward 1989) and devised for application mainly in physics.[1] Neo-mechanistic views partly stemmed from the desire to overcome such limits and account for explanations elaborated in a range of disciplines, especially those dealing with complex systems. Neo-mechanistic theories each intend to "offer an analysis of causation based upon a theory of mechanisms" (Glennan 1996, p. 49), which is meant as a theory of causal explanation as well. In general, among the features stressed the most by neo-mechanists we can recall the dynamic character of mechanisms and their being hierarchical multilevel structures, whose overall behaviour strongly relies on the internal organization of component parts and which can be structurally and/or functionally decomposed. Much attention has been drawn to the *interfield* character of mechanistic theories elaborated in disciplines such as, e.g., biology and neuroscience, to the *interlevel* character of mechanisms, and to their being governed by generalizations admitting exceptions and exhibiting different degrees of invari-

[1] Criticisms regarding very limited applicability apply even more to the "conserved-quantity theory", proposed by Phil Dowe (1992a, 1992b, 1995, 2000) and substantially embraced by Salmon in the mid-nineties (see e.g. 1994, 1997). Here I refer to Salmon's probabilistic mechanicism as elaborated mainly in the eighties. On the conserved-quantity theory, see Section 3.

ance. In point of fact, Salmon did not examine these aspects, which can be recognized as very significant steps in the attempt to be more deeply "grounded in the details of scientific practice" (Machamer, Darden & Craver 2000, p. 2). However, a few central features of neo-mechanistic views can be traced back to some of the core features of Salmon's reflections. In the first place, current mechanistic accounts stress the notions of *production* and *interaction*, which are then declined differently within the various theories. Mechanisms are taken to be systems of entities engaged in *productive* activities (Machamer, Darden & Craver 2000), or systems of parts that *produce* a given behaviour by *interacting* with each other (Glennan 1996, 2002). Emphasis is put on mechanisms' *doing* things. Although elaborated differently, these notions were already at the heart of Salmon's position, as appears from its key-definitions. In his theory, mechanisms of *causal production* operate –in stochastic ways– in our universe, through the *interactions* of causal processes. "Causal interactions are the agents of production: they produce changes in processes that intersect one another. Causal processes are the agents of propagation; they transmit causal influence throughout the universe" (Salmon 1990, p. 99. See also, e.g., 1980, 1984).[2] Moreover, according to Salmon in order for causal influence to be transmitted a shift from an event-ontology to a process-ontology is required and causal processes have to be spatio-temporally *continuous*. In turn, Machamer, Darden and Craver (2000) claim that what makes mechanisms' working regular "is the productive continuity between stages. [...]. Productive continuities are what makes the connections between stages intelligible" (Machamer, Darden & Craver 2000, p. 3). If Salmon's theory has been accused of circularity (see e.g. Dowe 1992a), neo-mechanistic positions including the idea of production in their very central definitions (Machamer, Darden & Craver 2000, Glennan 2002) are also subject to that criticism. The same defence applies to all these cases: as long as the circle is not vicious, but introduces clarifying elements, circularity per se is not a problem.

To shed light on causal explanation, a major distinction must be drawn between *constitutive* causation and *etiological* aspects. Although it plays a different role and is developed to a very different extent in the two views, such a distinction is present both in Salmon's and in one of the most successful neo-mechanistic positions, namely Carl Craver's. Craver (2007) stresses that constitutive explanations are those that proceed by describing internal mechanisms, while etiological explanations are concerned with entities and activities that preceded the phenomenon to be explained and brought it about. The variety of explanation Craver is mostly interested in is constitutive –or, as he also calls it, componential– mechanical explanation, insofar as it allows a phenomenon to be explained in terms of the organization of its component entities and activities.[3] Constitutive explanations

[2] As correctly pointed out by Glennan, "while Salmon has spent considerable effort subsequent 1984 trying to refine his characterization of processes and interactions, his view of the causal nexus as a network of interacting processes remains essentially unchanged" (Glennan 2002, p. 343. See also Glennan 2011, pp. 798-801).

[3] On the development of Cravers's own causal mechanical model of constitutive explanation, see especially Craver (2007, ch. 4).

are taken by Craver to be inward looking and downward looking, aiming to describe lower-level mechanisms; constitutive explanations are not one of the "divisions in the furniture of the world", but one of the possible "distinctive perspectives on an activity in a hierarchically organized mechanism" (Craver 2001, p. 67). Luc Faucher (2006) attributes the distinction between constitutive and etiological aspects to Craver himself, whereas Craver recalls Salmon's distinction (Craver 2001, pp. 69-70), acknowledges borrowing the idea of "constitutive causation" from Salmon (Craver 2007, p. 8, footnote 9; p. 108, footnote 1; p. 140, footnote 19), and criticizes Salmon for focusing exclusively on etiological causal explanation (Craver 2007, p. 8). For his part, Salmon was already well aware of the distinction and pointed out the difference between constitutive and etiological causal explanations: if we want to show *why* a given event *E occurred*, we must fill in the causally relevant processes and interactions that figure in *E*'s past; this is the etiological aspect of our explanation. On the other hand, if we want to show *why E has certain characteristics*, we must unravel its internal causal mechanisms, which lay bare the causal structure of *E* and account for its nature; this is the constitutive aspect of our explanation, which unravels why a phenomenon works the way it does (Salmon 1984, p. 207). These two notions are useful whenever we need to distinguish between a "how did this phenomenon originate?" and a "why is this phenomenon working this way?" kind of question. They can hence help pinpoint different features of scientific explanations and –as we will see in the following section– their focus on different aspects of the phenomena under investigation can be dictated by the context.

Another interesting feature of Salmon's account is that, while being thoroughly mechanistic, it admits of functional explanations too –unlike the received view which did not accommodate them. Aiming to grasp the kinds of reasoning adopted in scientific practice, and convinced that functional explanations represent an important class of explanations within at least some of the sciences (e.g. anthropology, sociology and biology), Salmon argues for the compatibility of functional and mechanical claims. "From a philosophical standpoint [...], functional explanations may be just as admissible as explanations of any other sort. As long as they play a crucial role in various branches of contemporary science" (Salmon 1998, p. 62), Salmon recommends they should not be ruled out on logical grounds. They are to be purged of any extrascientific, teleological element and spelled out in causal terms, describing effective cause-outcome relationships along the lines suggested by Larry Wright's "consequence-etiology" (1976), which Salmon believes is fundamentally correct but in need of being integrated with some deeper clarification of causation. Such a clarification is among Salmon's major "intellectual achievements" (Grünbaum 2004). Functional explanations can be interpreted as stating that the cause of a given feature (a biological trait, a social institution, ...) is the fact that its presence in the past has efficiently brought about a certain consequence; not only has the feature had such a consequence in the past, but this very fact is seen as causally responsible for its present instantiation. Functional explanations are hence taken to have a coarse-grained causal character. "Although some philosophers have maintained that the mechanistic explanation, when it can be given, supersedes the functional explanation, Wright holds that they are completely compatible" (Salmon 1998, p. 75), a view that Salmon fundamentally shares. Salmon does not develop an original and autonomous theory of functional explanation, but has the merit of stressing that functional explanations need not be *eliminated* in favour of mechanistic explanations, while considering them "a legitimate subset of causal explanations" (Salmon 1998, p. 7).[4] According to Salmon, functional explanations ultimately appeal to mechanisms, but only to coarse-grained ones, without specifying the details of causal processes and interactions. The link between the elaboration of mechanistic models and functional specifications was later highlighted by various neo-mechanists, who believe understanding mechanisms is coupled with an understanding of their own organization and their components' performing some functions, and thus extensively discuss how mechanistic and functional descriptions are related. Among neo-mechanists' reflections on the topic, let us just recall here Craver's, whose claims sound like some steps forward in the direction foreseen by Salmon: "grounding functional descriptions in the details of mechanistic organization will provide a set of criteria for assessing the precision and accuracy of functional ascriptions" (Salmon 2001, p. 73). Forcing functional ascriptions down to some finer-grained descriptions will also help us tell vague or too abstract from empirically adequate and possibly heuristically useful ones. Furthermore, conceiving of functional analyses as sketches of mechanisms, which can be integrated with multilevel mechanistic explanations, can prove useful in the clarification of mutual structural and functional constraints in a system's analysis.[5] Craver also points out how "functional descriptions can be tinged in a very direct way by our interests and biases" (Craver 2001, p. 73), thus suggesting that perspectival and contextual elements play a relevant role, as argued in the following section.

2. Mechanisms, the sciences and the role of context

Where and how are mechanical explanations to be adopted? As we have remarked, Salmon's theory of causal explanation is strictly intertwined with his theory of mechanistic causation. One of the main reasons for a mechanistic revival has been the issue of applicability, the very need to develop a perspective capturing the actual use of causal notions in sciences as practised, and applicable to a number of different fields, such as biology, neuroscience and cognitive science. Qualified defences of mechanistic causation and –more or less favourable– reflections on the role that mechanistic reasoning plays in the sciences have been elaborated, for instance, by Stathis Psillos (2004), Jim Bogen (2005),

[4] Furthermore, "a naturalistic causal interpretation of function enables us to accept functional explanations as legitimate components of natural science" (Salmon 1998, p. 9).

[5] See e.g. Piccini & Craver (2011).

Waskan (2011) and many others. Salmon's theory has been accused of not being widely applicable to the sciences, and possibly adequate –if at all– only with respect to physical and chemical causation. It is undeniable that Salmon's theory is far from accounting for all uses of the notion of cause, and that many of its requirements are hence barely mirrored in a number of disciplinary fields. However, some aspects of his position as developed in the eighties have been held to actually match the meanings and uses of mechanistic notions in the very fields that are the focus of neo-mechanistic theories, like the biomedical sciences. For instance, one of the most eminent scholars in the philosophy of the biomedical sciences, Kenneth Schaffner, has presented, as the most defensible and most suitable analysis of explanations in biology and medicine, a view of scientific explanation as an "intertwined mechanism and generalization 'overlap' model, [...] *heavily indebted to Salmon's theory*" (Schaffner 1993, p. 322, italics added).

Salmon's view has been deemed useful to grasp both important general features of medical causation and its historical development. His idea of the propagation of a mark over time, to which the identification of genuinely causal processes is anchored (Salmon 1984), has been considered fit to mirror the 19th century conception of the "localization" of a disease (see Vineis 2000), according to which the cause is an alteration that can be identified in the tissue and is characteristic of a certain agent (for example, the tubercle for tuberculosis). In this perspective, the cause is construed as a kind of signature persisting over time. This is a widespread concept in the history of medicine, especially following developments in molecular medicine. Salmon's position is thus believed to reflect more general developments in medicine:

> molecular research almost literally refers to Salmon's idea of a mark that can be followed along time. [...]. This is the context in which the new causal pathways suggested by the intertwining between the probabilistic science of epidemiology and the idea of 'marks propagating over time' of molecular biology can create and reinforce new causal hypotheses (Salmon 1984, p. 653).

Epidemiology, in turn, is interested –amongst others– in the construction of transmission models of diseases, which shall incorporate interactions between individuals and represent how they are linked to a population network. Such models make a key-use of such notions as *interaction* and *transmission*, to go beyond the identification of risk factors and black-box models, "into the realm of explaining *causal processes*" (Susser, Schwartz, Morabia & Bromet 2006, p. 39, italics added).

Salmon has also been held to provide some useful concepts for causal analysis in the social sciences. While his most specific works in this respect refer to archaeology (see Salmon 1982, 1992, Salmon & Salmon 1979), economics too has been suggested as a field of enquiry in which some of the notions he elaborated can dovetail and be profitably adopted. In particular, according to Uskali Mäki

(1992),[6] Salmon's view of causation can be drawn upon in analyzing the causal structure of the Austrian theory of the market process. The notions of causal production, causal propagation and, especially, causal process can be employed in this respect: Austrian theory of the market process can be defined as a causal process theory, with entrepreneurship acting as a *productive* agent, and market prices working as *propagators* of information, i.e. causal influence, from one part of the economy to another. Moreover, according to the Austrian theory, "the market allegedly generates a spontaneous, reproductive order without the help of any external causal agent", and can hence be "represented as a self-supporting process" (Mäki 1992, p. 44).

One could argue that authors referring to Salmon's theory of causation do so only by virtue of some relevant changing and much adapting of its notions, being too strong in its core definitions to enjoy broad applicability. While needing further elaboration, and specification according to the field of application, the notions of process, production and propagation on which Salmon grounds his view on "the causal structure of the world" in the eighties (Salmon 1984) have been partly invoked to grasp scientific causation. At the same time, the cases listed above are by no means meant to claim that Salmon's position can be easily and convincingly applied to the mentioned scientific disciplines as it stands. Later Salmon himself was increasingly aware of these limitations. While neo-mechanists accused his theory of being silent about *different kinds* of productive activities and mechanisms as investigated by the majority of disciplines, not only did Salmon admit that his account "should hold in the natural sciences –including biology, but not quantum mechanics", but he also became "not confident that it [was] suitable for psychology and the social sciences" (Salmon 2002, p. 131).[7]

In general, Salmon was much more concerned with elaborating some clear views of *what* causal processes, causal production and propagation *are*, than with shedding light on *what* they are –or can be– *good for* in the sciences.[8] The examples he makes in his works span a very broad set of phenomena, and range from bacterial infections to food intoxication, radioactive decay, delinquency acts, the collision of billiard balls and the presence of a worked bone in an archaeological site. When actual science is referred to, however, physics (except for quantum physics) is no doubt what Salmon mainly had in mind. Nowadays the debate flourishes on whether and for which purposes specific notions of mechanism can be devised to fit certain disciplinary realms (see e.g. Steel 2004, Reiss 2007, Gerring 2008, Broadbent 2011, Campaner 2011a, 2011b, Leuridan & Weber 2011, Little 2011), or whether some very general notion of mechanism

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[6] I would like to thank Prof. Mäki for drawing my attention to this work of his.

[7] In Salmon (1984, p. 278), he had claimed, instead, that his theory of causal explanation could also be reasonably adequate in psychology and in the social sciences.

[8] Reflections on what causal processes are and on what they are good for are presented in Hitchcock (2004), which, though, deals with the usefulness of the notions of causal process and causal interaction with respect to a philosophical analysis of causation, not their actual role in the sciences.

can be arranged that will apply in all –or most– circumstances (Illari & Williamson 2012). Salmon constituted a fundamental starting point and provided crucial hints to address these kinds of questions.

It must be added that, where possible, Salmon's theory of mechanistic explanation can be applied only if not interpreted literally, in a strict sense, but as referring to *incomplete* mechanisms. In order to make his theory more widely applicable and to get closer to the actual elaboration of explanations in scientific practice –and only for these purposes– Salmon came to admit that the level of graininess of a mechanistic description and the context in which it is drawn play a relevant role. "The complete causal structure is a fact of nature that exists quite independently of our knowledge or interests; it is not epistemologically relativized. It is an extremely complex entity, but that is because the world is extremely complex". At the same time, "statements about the relations between causes and effects are usually highly selective, and they are typically context-dependent" (Salmon 2002, p. 126). An important aspect also highlighted in the neo-mechanist literature concerns the very relationship between the level of fine-graininess that the description of a mechanism reaches and the context in which such a description is drawn. The possibility and opportunity of elaborating mechanisms' sketches or schemas has been pointed out (see Machamer, Darden & Craver 2000, pp. 16-18) and some perspectival aspect has been recognized. According to Craver, "describing an item's mechanistic role is a perspectival affair" (Craver 2001, p. 73), and Jim Bogen, in turn, maintains that the enumeration of a given mechanism's components, their activities and the factors that influence their behavior is never complete; the amount and kinds of details included always vary from one context to another, depending on people's interests, background knowledge, cultural and social factors (Bogen 2005, p. 398, footnote 2). Even more recently, while stressing that the identification of mechanisms is not guided by completely arbitrary choices, Darden states:

> when biologists identify mechanisms, there is an inherent perspectival aspect as to what is picked out of interest from all the goings on in the world. First, the choice of phenomenon is relative to the scientist's interests. [...]. To some extent and in some cases, the choice of beginning, ending, topping-off, and bottoming-out points in the description of a mechanism may also be related to the interests of the investigator (Darden 2008, p. 960).

It is thus worth recalling that, while maintaining his ontic view, Salmon too in some of his later contributions acknowledged that pragmatic elements enter into causal analyses. The instances we select and the level of description we choose are context-dependent. Much of the complexity characterizing causal situations is always dispensed of for the purposes of causal analysis in a given context; pragmatic considerations are recognized to affect both the choice of the level of abstraction at which the analysis is to be carried out and the identification of what is to be deemed relevant from an explanatory point of view. If Salmon already recalls some contextual aspects at the end of his (Salmon 1984) and, to a greater extent, at the end of his (Salmon 1989) –especially by referring to Peter Railton's position and to the possibility of reconciling the mechanistic and the unificationist approaches– this line of thought gained force later in his life. In "Causality and Explanation: A Reply to Two Critiques" (Salmon 1997) he claims: "when it comes to practical investigation of actual processes pragmatic considerations determine the level of analysis" (Salmon 1997, pp. 464). It is one thing to be concerned, e.g., with molecular collisions, and another to be dealing with collisions of objects. "We gain insight into causality by operating at a rather rarefied theoretical level, recognizing, of course, that we must often descend from such abstract heights when it comes to practical investigations" (Salmon 1997, pp. 464). While aiming to elaborate a fully objective and realistic account of causal relations –with *statistical causality* defined in terms of statistical relationships and *aleatory causality* defined in terms of physical processes and interactions– Salmon acknowledges that the instances our causal analyses select can depend on a number of contingent, highly variable, matters. "The selection of the causal field is guided by pragmatic considerations, and is, therefore, context dependent" (Salmon 2002, p. 125). He still claimed that there is a thoroughly objective causal structure underlying phenomena, but also came "to believe that the 'cause-effect' terminology is heavily context-dependent –involving human background knowledge, interests, and purposes" (Salmon 2010, p. 11), with a prominent way in which contextual considerations strongly enter into our representation of the causal structure of the world being the choice of the processes and interactions taken as elementary.[9]

Although elaborated mostly from the late nineties, such reflections on contextual matters still refer to Salmon's theory of causal explanation put forward from the early eighties, and not to the conserved-quantity theory he embraced in the nineties to escape –as we shall see below– any appeal to counterfactuals in the identification of genuine causal processes.

3. Appeal to counterfactuals "with great philosophical regret". Or not?

One of the crucial concerns in dealing with mechanistic causation has to do with the *assessment* of mechanistic connections: how do we establish that a productive link is in place? How do we identify what count as parts constituting a causal mechanism, as opposed to some non-causal structure? The need to elaborate criteria to tell genuinely mechanistic links from non-causal ones has been increasingly stressed, and neo-mechanists have been extensively considering the issues of the assessment of productive relations and discovery of mechanistic systems. In the last few years both actual and hypothetical interventions have been more and more explicitly recognized as playing a crucial part in the iden-

[9] Although he does not develop his view on the issue, Salmon states he does not hold a reductionist standpoint (Salmon 2010, p. 12).

tification of mechanisms' components and functioning, often appealing to Jim Woodward's theory (Woodward 2003) and the notion of invariance under intervention. In his view, a relation's being causal has to do with whether it would remain stable if, perhaps contrary to actual facts, certain interventions were to occur. Woodward has suggested as a core idea that of "interventionist counterfactuals", or "active counterfactuals" –where counterfactuals are not to be understood in terms of similarity between possible worlds, but as claims regarding what would happen if certain interventions were to be performed, by either men or nature.[10] Counterfactuals are here interpreted as claims about the outcomes of well-specified hypothetical interventions. When possible, the corresponding experiments are carried out; in many cases interventions cannot be realized, or cannot be realized *yet*, and are hence just hypothesized. Interventionist counterfactuals are thus likely to be particularly suited to situations in which experimentation is extremely difficult for theoretical, practical and/or ethical reasons (e.g. psychiatry).

On the mechanist side, Glennan has explicitly borrowed from Woodward the notion of invariant, change-relating generalization in his definition of mechanism (Glennan 2002). In spelling out the importance of causally relevant properties to explain why a given effect is produced, he claims that "causal relevance is essentially a counterfactual notion" (Glennan 2010, p. 365): had the relevant properties been different, the effect would have been different too. Manipulations of what are believed to be potentially causally relevant variables can be used to establish the actual relevance of these variables to classes of events.[11] While Craver supports a "manipulationist view of causal relevance" (Craver 2007, pp. 93-97) together with his mechanistic account of explanation, another contemporary author, Tabery, advances the notion of "difference mechanism" (Tabery 2009, pp. 654-659): mechanisms are made up of many difference-making variables, which can take different values; interventionist manipulations –either actual or counterfactual– made on the values of these variables result in changes in the outcome. Nature itself is held to be interventionist. Like Woodward, Tabery is interested in freeing the notion of intervention from any anthropocentric flavor.

Less explicit but equally significant hints on the use of interventions –expressed in counterfactual terms– in the identification of mechanisms can also be found in earlier works belonging to the neo-mechanist perspective. To provide a description of mechanisms accounting for the different levels into which they articulate, Craver, for instance, presents a "taxonomy of interlevel experimental strategies" (Craver 2002, pp. 91-95): we perform an *experiment* in a given way, ac-

[10] While holding a manipulationist theory, Woodward has also suggested a "counterfactual account" of "what a mechanism is" (Woodward 2002), and has more recently stated that "some of the intuitions behind the geometrical/mechanical approach can be captured by thinking in terms of spatio-temporally organized difference-making information" (Woodward 2011, p. 409).

[11] This may be the case even though one does not understand precisely how these variables act, i.e. one does not know yet which mechanisms produce such events.

cording to a given model and following a given strategy because we believe that, *were we* to intervene at a certain level, something *would occur* at the previous or next level. Darden, addressing the discovery of mechanisms, speaks of "forward chaining" and "backward chaining" (Darden 2002, pp. 362-365) strategies that can be employed on the basis of conjectures on what entities and activities *could have been* at a certain stage n *if they had been* such and such at a stage n+1 or n-1. According to Machamer (2004), intervention is a good strategy for uncovering mechanisms or for finding causal connections, where an intervention is taken to be something by means of which one can stop or change a putative activity to find out what happens. Within a mechanistic perspective, "active counterfactuals" are thus employed to uncover mechanistic activities.[12]

The usefulness of counterfactuals as reliable tools to distinguish genuine causal relations from non-causal ones, and, more importantly, the possibility of avoiding difficulties concerning counterfactuals *by interpreting them experimentally* was already suggested by Salmon in the mid-eighties. The criteria he elaborated in his theory to tell causal processes and causal interactions from non causal ones were given a counterfactual formulation in the wake of criticism, in particular by Nancy Cartwright (see Salmon 1998, p. 252). According to Salmon, 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 an intersection between two causal processes such that, *had* they *intersected*, both their structures *would have been modified* from that point onwards without any additional intervention. Philip Kitcher's and, especially, Phil Dowe's objections were then formulated –stressing the risk of Salmon's theory's actually turning into a counterfactual theory of causation, betraying its empiricist framework– and the conserved quantity theory was put forward (see Kitcher 1989, Dowe 1992a, 1992b, 1995, 2000). In the C-Q theory, a causal process is defined as a world-line of an object which manifests a conserved quantity; a causal interaction is defined as an intersection of world-lines which involves an exchange of a conserved quantity, and no appeal to counterfactuals is made. While initially requiring some adjustments (Salmon 1994), Salmon was sympathetic with Dowe's position, which preserves some of his own theory's main aims, and in the late nineties essentially embraced it (Salmon 1997).

Salmon reveals that he had appealed to counterfactuals "with great philosophical regret" (Salmon 1998, p. 18), being worried they could constitute a drawback for his position, and he was glad to abandon them for a different process theory, the conserved-quantity theory, which gets rid of counterfactuals. However, before renouncing counterfactuals, he had suggested that they could be accounted for experimentally. Although counterfactuals carry difficulties with them, according to Salmon "science has a direct way of dealing with the kinds of counterfactual assertions we require, namely, the experimental approach." (Salmon

[12] On the use of counterfactuals in Woodward's theory see Psillos (2004); on their use in neo-mechanistic theories, see Campaner (2006).

1984, p. 149) Salmon definitely refused to appeal to possible worlds and the like (see e.g. Salmon 1997, p. 476), and suggested a way to interpret counterfactuals that could be compatible with his empiricist and realist perspective. Back in (1984) he stressed how in well-designed controlled experimental settings scientists decide which conditions are to be kept fixed and which to vary for the purposes of the experiment, and points out that, to interpret counterfactuals, we have to think of *hypothetical experimental procedures*: the ability to transmit a mark and the property of being a causal interaction can be assessed by performing certain kinds of experiments (Salmon 1984, p. 147). He believed this interpretation was fully objective and allowed to show how some processes are genuinely causal, while others are not. Furthermore –he holds– even though we can often play an active part in ascertaining whether a process is causal, "human agency plays no essential part in the characterization of causal processes or causal interactions" (Salmon 1984, p. 173). They would be such even if no human agent were to perform the experiments.

According to Craver, his manipulationist view of causal relevance

> contrasts with Salmon's (1984, 1998) [...] transmission view and with any view that construes causal relevance as a kind of physical connection: a cement, glue, spring, or string [...]. While many relationships of causal relevance are also relationships of connection in this sense, the focus of the connection misses the core idea of causal relevance: the idea that causes make a difference to their effects" (Craver 2007, pp. 200-201).

Although "many cases of causation involve transmission of marks or conserved quantities, this is but one way for something to make a difference to something else", and Craver maintains it is the manipulationist approach he recommends that "makes this reliance on difference-making (*and the experimental procedure to test it*) explicit" (Craver 2007, p. 86, italics added). The concept of mark transmission does not suffice to capture all different kinds of causal influence, but some sense of experimental procedure to tell genuine causes was indeed included –though not developed enough– in Salmon's view. Even if Salmon undeniably meant to understand causation as a physical connection, grasping causal relevance was one of his main concerns too, and the appeal to a counterfactual formulation of his theory's criteria can be seen as an attempt to deal with this. If "to manipulate items [...] is crucial evidence for establishing causal and explanatory relationships among the mechanism's components" (Craver 2007, p. 132), imposing marks on processes to establish whether they are genuinely causal can be seen as a –inadequate or controversial, but analogous– means to the same effect. Salmon's suggestion in the eighties of an experimentalist interpretation of counterfactuals can be regarded as paving the way for some of the most recent solutions appealing to interventions and interventionist counterfactuals. It is now recognized that one can appeal to counterfactuals for heuristic purposes, to elucidate causal relevance and identify causal systems, without embracing a counterfactualist approach. Hints at the way in which the neo-mechanist perspective is incorporating counterfactuals to assess whether a genuine causal nexus is in place can thus be found in Salmon's probabilistic mechanicism and his conceptual apparatus as presented in the eighties.[13]

4. Concluding remarks

Without denying that much progress has been made on the topic, I have argued that the mechanistic revival is much more indebted to Wesley Salmon than is currently recognized. Some of his intuitions can be now regarded as heralding the developments of his philosophical orientation. At the end of the eighties (1989) he was expecting a *new consensus with respect to scientific explanation* could be built, which might show how, in particular, the causal-mechanical and the unificationist account were compatible and could complement each other. Other suggestions were included in Salmon's view which were perhaps not stressed or developed enough, but which have actually entered the most successful contemporary accounts of mechanistic causation. I have tried to illustrate how some causal theories belonging to different philosophical traditions, such as the mechanistic and the manipulative, have recently resumed a dialogue, especially through the appeal to counterfactuals, one of the elements for which Salmon was criticised the most. Far from converging into some form of *consensus* on causation, such elements as a deep concern for the clarification of causal relevance and the appeal to counterfactuals to be interpreted experimentally can provide some ground for a –at least partial– rapprochement between different theories of causation, a rapprochement the latter-day Salmon might have approved of.

[13] Salmon also admits that counterfactuals play some role within explanation. In addressing criticisms raised by Hitchcock, he says: "when an explanation is offered, it is pertinent to consider what would have happen if the explanans had not been obtained" (Salmon 1997, p. 475). Salmon then continues: "This is, I think, a relatively unproblematic counterfactual statement because it is supported by well-established assertions of statistical relevance [...]. Counterfactuals, like statistical relevance relations, are often effectively tested by controlled experiments" (Salmon 1997, p. 476. On this see also Galavotti 1999).

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