Causation and Gerrymandered World Lines: A Critique of Salmon*

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In this paper I examine Salmon's response to two counterexamples to his conserved quantity (CQ) theory of causation. The first counterexample that I examine involves a time-wise gerrymandered world line of a series of patches of wall that is absorbing energy as a result of being illuminated in an astrodome. Salmon says that since the gerrymandered world line does not fulfill his "no-interaction requirement," his CQ theory does not suffer from the counterexample. But I will argue that his response fails both at a theoretical level and at a practical level. In so doing I point out a problem for CQ theorists' definition of a causal interaction. The second counterexample is concerned with a time-wise gerrymandered world line of a series of patches that are in shadow, in Hitchcock's well-known example. Salmon's response is based on a principle that Salmon thinks is derivable from the concept of a conserved quantity. However, I argue that the principle has a counterexample.

1. Introduction. The conserved quantity (CQ) theory analyzes causation into causal interactions and causal processes, where both the notion of a causal interaction and that of a causal process are defined in terms of conserved quantities such as energy, electric charge, etc. Suppose that a child hits a ball with a bat. According to CQ theory, when the ball collides with the bat they causally interact with each other in that they exchange, for example, energy at the moment of collision, and the motion of the

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flying ball after collision is a causal process in that the ball possesses or transmits an amount of energy at every moment of its history. Thus CQ theory analyzes the causal history of the ball into causal interactions and causal processes.

In this paper I will examine two counterexamples, i.e., the astrodome counterexample and Hitchcock's counterexample to CQ theory, and then criticize the responses to them provided by Salmon. In doing so I will point out a problem for Dowe's and Salmon's definition of a causal interaction.

The structure of the paper is as follows: in Section 2, I outline the two versions of CQ theory proposed by Dowe and Salmon; in Section 3, I argue that Salmon's answer to the astrodome counterexample fails because of his own necessary defense of the classical free-falling body example; in Section 4, I argue that the principle on which Salmon's response to Hitchcock's counterexample is based allows a counterexample such that Salmon's response fails; in Section 5, I reconsider the astrodome counterexample and argue that Salmon's response to it fails once more because, contrary to his contention, there are no interactions between the gerrymandered world line of a series of patches of wall and the light rays.

2. The Two Versions of CQ Theory of Causation. Salmon and Dowe are the most well-known advocates of CQ theory, but their formulations of the theory are not identical. Dowe (2000, 90) summarizes his CQ theory by the following two propositions:

DCQ1. A causal interaction is an intersection of world lines that involves exchange of a conserved quantity.

DCQ2. A causal process is a world line of an object that possesses a conserved quantity.

Salmon's CQ theory (1997, 462; 468) can be summarized by the following three propositions:

SCQ1. A causal interaction is an intersection of world lines that involves exchange of a conserved quantity.

SCQ2. A causal process is the world line of an object that transmits a nonzero amount of a conserved quantity at each moment of its history (each space-time point of its trajectory).

SCQ3. A process transmits a conserved quantity between A and B ($A \neq B$) iff it possesses [a fixed amount of] this quantity at A and at B and at every stage of the process between A and B, without any interactions in the open interval (A,B) that involve an exchange of that particular conserved quantity.

The two versions of CQ theory differ only over the notion of a causal process. It will be useful to make their differences clear. Suppose that a gas molecule moves freely without interactions, collides with another molecule, and then moves freely again. Salmon (1994, 258), who requires that for a process to be causal there be no interactions involving exchange of the conserved quantity in question, analyzes the world line of the gas molecule not into a single causal process but rather two distinct though connected processes. Likewise, Salmon (1997, 464) analyzes a world line of a classically-described free-falling body on earth into "a continuous series of interactions" between the body and the gravitational field. In contrast, Dowe, who requires only possession of a conserved quantity, will analyze the world line of the gas molecule and that of a classical free-falling body into single causal processes.

In connection with this, Dowe points out that, since "actual causal processes do not operate in the absence of interactions," Salmon's account "renders useless the notion of a causal process, as opposed to an interaction" (1995, 331). Salmon replies that his CQ theory is at a rarefied theoretical level and "when it comes to practical investigation" we can regard the world line of a classical free-falling body as a single causal process with "appropriate pragmatic considerations" (1997, 464).

3. The Astrodome Counterexample and Salmon's Response. Suppose that a beacon rotates rapidly at the center of an astrodome and a luminous spot produced by the light from the beacon travels around the wall. Consider a world line w_1 defined as follows:

> A world line w_1 consists of spatio-temporal points (x, t) on a space-time diagram, where x is occupied by a patch on which the spot of light appears at time t.

The world line w_1 is a time-wise gerrymandered world line of a series of patches that is absorbing energy as a result of being illuminated. Salmon asserts that w_1 qualifies as a causal process by Dowe's theory because "w_1 manifests [possesses] energy throughout the period during which the spot travels around the wall," but "it is not the world line of a causal process because the energy is not being transmitted" (1994, 257). He concludes that we must insist on the requirement of transmission of a conserved quantity in order to disqualify the gerrymandered world line w_1 from being a causal process.

However, Dowe (1995, 326–31) claims that Salmon's CQ theory rather than his CQ theory suffers from the astrodome counterexample. He argues that Salmon's CQ theory suffers from it "since, according to that [Salmon's] account, transmission amounts just to regular appearance" (327). Salmon (1997, 466) complains that Dowe misses the important fact that there is an interaction between w_1 and the world line of the light ray traveling from the beacon at every stage of w_1 that involves an exchange of energy. If Salmon's complaint were well taken, then the astrodome example would not pose a problem for his CQ theory, because w_1 would not satisfy the "no-interaction requirement" in (SCQ3).

Unfortunately, I think Salmon's complaint is groundless because there are no interactions between w_1 and the light rays. I will argue for that in detail in Section 5. For the sake of argument, suppose that there are such interactions. Even then Salmon's response raises a question. Salmon, as we have seen, analyzes a world line of a classical free-falling body into a continuous series of interactions. This means that on Salmon's CQ theory w_1 is analyzed in the same way as the world line of a classical free-falling body. If so, can we consider the former as a single causal process with appropriate pragmatic considerations, like the latter? It is evident that Salmon wishes to claim that w_1 cannot be regarded as such with any pragmatic considerations. According to him, what makes a process causal is transmission of something, but w_1 does not transmit anything. Then on what grounds can the world line of a free-falling body, but not w_1, be regarded as a causal process with appropriate pragmatic considerations, each being a continuous series of causal interactions at a rarefied theoretical level?[1]

Salmon cannot answer my question by saying that the energy of w_1 is present only because it is constantly being supplied by an outside source but the energy of the free-falling body is not (Salmon 1997, 466). For "supply" is a causal term. Here, we are strongly tempted to appeal to counterfactuals.[2] Without interactions with the gravitational field, the amounts of such conserved quantities as energy and linear momentum possessed by the classical free-falling body would remain constant, respectively. In contrast, without interactions with the light rays, the amounts of conserved quantities possessed by w_1 would not remain constant. Thus Salmon might propose that a world line that fulfills all the requirements of a causal process except the no-interaction requirement can be regarded as a single causal process with appropriate pragmatic considerations only if this counterfactual is true at every stage of the world line: if it did not interact with other processes, the amounts of conserved quantities possessed by it would remain constant, respectively.[3]

Unfortunately, this answer involves counterfactuals, and it is precisely because of the involvement of counterfactuals that Salmon rejected his

1. On this point I am much indebted to Inkyo Chung.

2. Kitcher (1989, 463) raised a problem of "no further interactions" for the mark theory that is similar to mine and proposed a solution to it involving counterfactuals.

3. On this point I am indebted to an anonymous referee.

mark theory. Therefore, if he were to give that answer to my question, he would lose his main motive for CQ theory, because his CQ theory would also involve counterfactuals in "descending from abstract heights" (Salmon 1997, 464).

Another claim that I would like to make—this is related to what I have been saying—is that Salmon's interpretation of how his theory applies to such processes as a world line of a free-falling body and that of a gas molecule colliding with other molecules is mistaken.[4] For, contrary to his interpretation, the processes qualify as single causal processes by his own CQ theory even at a theoretical level. Note that the world line of a free-falling body possesses a fixed amount of energy at every stage, without any interactions that involve exchange of energy. What happens to a free-falling body during its fall is merely that its gravitational potential energy is transformed into kinetic energy. Its mechanical energy, the sum of its gravitational potential energy and its kinetic energy, does not change. Then, according to (SCQ2), the world line of a free-falling body is a single causal process. Of course, there is a continuous series of interactions, between a free-falling body and the gravitational field, which involve exchanges of linear momentum, so the world line of a free-falling body does not possess a fixed amount of linear momentum. But, this does not prevent the world line of a free-falling body from being a single causal process. On Salmon's CQ theory, a process is a single causal process as long as it possesses at least one fixed conserved quantity, even if the amounts of other conserved quantities change.[5] Like the world line of a free-falling body, a world line of a gas molecule colliding with other molecules qualifies as a single causal process by Salmon's CQ theory. For at every stage it possesses a fixed baryon number, a conserved quantity related to the number of nucleons (protons and neutrons), without any interactions that involve exchange of baryon number.

My interpretation will actually enable Salmon, without excessive involvement of pragmatic considerations, to meet Dowe's objection that his CQ theory has pragmatic difficulties.[6] For his CQ theory, on my interpretation, analyzes many actual processes interacting with other processes into single causal processes at a theoretical level. My interpretation may also enable him to dismiss my criticism with regard to the distinction between w_1 and the world line of a free-falling body because he can now

4. An anonymous referee gave me a clue to this point.

5. I think Salmon made a mistake in saying that his invariant theory implies that "a causal process does not enter into any causal interactions" (1994, 258). For Salmon's invariant theory is not different from his CQ theory in the respect I discuss here.

6. I do not deny that pragmatic considerations play a role in determining whether a process can be regarded as a single causal process or not.

say that they are analyzed differently at a theoretical level. As we have seen, the world line of a free-falling body is analyzed into a single causal process. On the other hand, given that energy is the only conserved quantity of which w_1 possesses a fixed amount at every stage, w_1 is analyzed not into a causal process but into a continuous series of interactions (of course, on the supposition that w_1 continuously interacts with light rays). A continuous series of interactions is not a causal process.

However, we can supplement the astrodome example in such a way that w_1 possesses a nonzero amount of a conserved quantity other than energy. Hitchcock's example in the next section highlights this point. Furthermore, as I will argue in Section 5, there are no interactions between w_1 and the light rays.[7]

4. Hitchcock's Counterexample and Salmon's Response. Suppose a shadow moves across a metal plate that has a uniform nonzero charge density on its surface in such a way that the area of the plate in shadow remains constant (Hitchcock 1995, 314–15). A world line w_2 is defined as follows:

> A world line w_2 consists of spatio-temporal points (x,t) on a space-time diagram, where x is occupied by a patch which is in shadow at time t.

The world line w_2 is a time-wise gerrymandered world line of a series of patches that is in shadow.

It is evident that w_2 is not a causal process. In this case, however, Salmon cannot disqualify w_2 from being a causal process on the ground of his no-interaction requirement because clearly there are no interactions involving exchange of electric charge in the history of w_2. So, he provides another kind of solution.[8]

Salmon's solution (1997, 473) to Hitchcock's counterexample is based on (P1):

> (P1) When two or more processes possessing a given conserved quantity intersect (whether they interact or not), the amount of that quantity in the region of intersection must equal the sum of the separate quantities possessed by the processes thus intersecting.

Salmon says:

> In the reformulated version of Hitchcock's example, this [P1] means

7. An anonymous referee helped me express my idea succinctly.

8. Hitchcock's example places Salmon in an awkward position. Note that both the astrodome counterexample and Hitchcock's counterexample are concerned with time-wise gerrymandered world lines. Moreover, apparently it is the gerrymanderedness of the world lines that causes troubles. This suggests that solutions to them had better have much in common. But Salmon's solutions do not.

> that if the region of the surface in shadow were transmitting electric charge, the charge density in the portion of the surface that is in shadow would have to be augmented as the shadow passes over it, and then reduced as the shadow goes beyond. This condition is not fulfilled, however . . . (1997, 473)

In these passages Salmon seems to hold that only those processes that transmit, as well as possess, a conserved quantity fulfill (P1). But, apparently (P1) does not require transmission of a conserved quantity. Let me state what I think he means in a tractable form.

(P1*) When two or more processes *transmitting* a given conserved quantity intersect (whether they interact or not), the amount of that quantity in the region of intersection *equals* the sum of the separate quantities possessed by the processes thus intersecting.

I will now attempt to clarify Salmon's argument. Pick out a patch of the plate that is exactly in shadow at a certain time t_1. At every stage the world line w_3 of this stationary patch is transmitting an electric charge whose amount equals that of the electric charge possessed by w_2. Salmon's argument goes as follows:

(1) w_2 is transmitting an amount Q of electric charge at every stage. [premise]
(2) w_3 is transmitting an amount Q of electric charge at every stage. [premise]
(3) (P1*). [premise]
(4) The amount of electric charge in the region of intersection between w_2 and w_3 is 2Q at t_1. [from (1), (2), and (3)]
(5) But, in fact, the amount is Q at t_1. [premise]
(6) Contradiction. [from (4) and (5)]

The fact that this valid argument leads to a contradiction implies that at least one of the premises (1), (2), (3), or (5) is false. Salmon rejects premise (1).

Salmon argues that (P1*) is not to be rejected because it "follows logically from the fact that the quantities in question are conserved" (1997, 473). He goes so far as to switch from invariant quantity theory to conserved quantity theory to ensure the plausibility of (P1*). However I am not sure that (P1*) follows logically from the concept of a conserved quantity. In fact, (P1*) allows a serious counterexample.

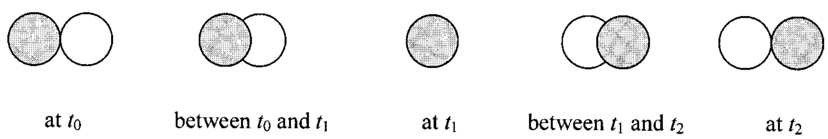
Consider a world line s_1 of a complex system composed of billiard balls A and B, and, a world line s_2 of a complex system composed of billiard balls B and C. When they intersect (without interactions), the amount of energy in the region of intersection is <energy of A + energy of B +

energy of C>. This is different from the sum of the separate amounts of energy possessed by s_1 and s_2, that is, <energy of A + 2×energy of B + energy of C>. Does this mean that one of s_1 and s_2 is not transmitting energy? Certainly not. Then we better reject (P1*), contrary to Salmon's conviction that it follows logically from the concept of a conserved quantity.[9]

Salmon might respond that s_1 and s_2 are not "separate" processes, so (P1*) can be amended easily by inserting "separate" in the clause, "When two or more [separate] processes . . . ". [10] Then which processes are separate and which processes are not? I think the most plausible answer is that two processes are not separate if and only if it they intersect (without interactions) with each other at every stage. According to this construal, s_1 and s_2 are not separate. Thus the billiard balls example does not cause trouble for the amended principle, which I call (P2). Moreover, Salmon's argument remains intact. For w_2 and w_3 in Hitchcock's example are separate processes, so when we replace (P1*) with (P2) in Salmon's argument, (4) still follows from (1), (2) and (3).

However, I am afraid that this response does not work. Suppose that in Hitchcock's example the shadow moves on the metal plate in the following way: w_2 starts to intersect with w_3 at a certain time t_0; the region of intersection increases thereafter; w_2 exactly overlaps w_3 at t_1; and then the region of intersection decreases; finally w_2 finishes intersecting with w_3 at a later time t_2.

[Diagram]



Filled circles represent w_2, that is, a series of patches of metal plate that are in shadow moving from left to right, and unfilled circles represent w_3, that is, a stationary patch that is exactly in shadow at t_1. Let 'w_4' denote a gerrymandered world line of a series of patches from t_0 to t_2 that is in shadow, and 'w_5' denote a world line of the stationary patch from t_0 to t_2

9. I think, as an anonymous referee pointed out, that the counterexample can be generalized.

10. The possibility of this response was brought to my attention by an anonymous referee. The referee mentioned another response, that the energy possessed by s_1 and the energy possessed by s_2 are not "separate quantities." In my opinion it is probable that "separate quantities" are analyzed in terms of "separate processes," hence the latter response is not different from the former.

that is exactly in shadow at t_1. w_4 is an extended-in-time segment of w_2 from t_0 to t_2, and w_5 is an extended-in-time segment of w_3 from t_0 to t_2. It is clear that Salmon will attempt to disqualify w_4 from being a causal process in the same way as he did w_2. But in the case of w_4 Salmon's argument is not valid, because (4′) does not follow from (1′), (2′) and (3′):

(1′) w_4 is transmitting an amount Q of electric charge at every stage.
(2′) w_5 is transmitting an amount Q of electric charge at every stage.
(3′) (P2)
(4′) The amount of electric charge in the region of intersection between w_4 and w_5 is 2Q at t_1.

Since w_4 and w_5 intersect (without interactions) with each other at every stage, they are not separate. Accordingly, (P2) does not apply to the intersection between w_4 and w_5. Thus Salmon cannot disqualify w_4 from being a causal process on the ground of (P2). (P1*) cannot be saved simply by inserting "separate" into it.

Fortunately a different way out is available to Salmon. Note that the billiard balls example is different from Hitchcock's example in an important respect. Although the amount of energy in the region of intersection does not equal the sum of the separate amounts of energy possessed by s_1 and s_2 in the billiard balls example, the amount of energy in the total region occupied by s_1 and s_2, which is $<$energy of A + energy of B + energy of C$>$, remains constant through time. By contrast, the amount of electric charge in the total region occupied by w_2 and w_3 in Hitchcock's example changes through time. While w_2 and w_3 do not intersect with each other, the amount of electric charge in the total region is 2Q. On the other hand, while w_2 and w_3 intersect exactly with each other, the amount is Q.

In light of this consideration Salmon may replace (P1*) with (P3) stated as follows:

(P3) When two or more processes transmitting a given conserved quantity are isolated from the outside world, the amount of that quantity in the total region occupied by the processes remains constant through time.

It is evident why there is the requirement that the processes in question be isolated from the outside world. If they causally interact with the outside, the amount of a conserved quantity possessed by them will change through time.

(P3) enables us to block the billiard balls counterexample without involving bothersome problems with separateness of processes. Moreover it is clearer how (P3) is related to the concept of a conserved quantity. For when we define the total amount of a conserved quantity of processes as the amount of that quantity in the total region occupied by the processes, (P3) seems to be deducible from the conservation law that the total amount of a conserved quantity of processes isolated from the outside world remains constant through time.

Now let us revise Salmon's argument. The revision takes more than substituting (P3) for (P1*) in the original argument. The argument appropriately reformulated is:

(1) w_2 is transmitting an amount Q of electric charge at every stage. [premise]
(2) w_3 is transmitting an amount Q of electric charge at every stage. [premise]
(3) When w_2 and w_3 do not intersect with each other, the amount of electric charge in the total region occupied by them is 2Q. [premise]
(4) (P3). [premise]
(5) When w_2 and w_3 intersect exactly with each other, the amount of electric charge in the total region occupied by them is 2Q. [from (1), (2), (3) and (4)]
(6) But, in fact, the amount is Q. [premise]
(7) Contradiction. [from (5) and (6)]

As with the original argument, Salmon may propose to reject premise (1) to avoid contradiction.

Unfortunately, there is something problematic even in the revised argument. Given the argument we know only that (1) or (2) should be rejected. We do not know yet which of (1) or (2) should be rejected. In order to reject (1), Salmon would have to explain on what grounds w_3 (but not w_2) is transmitting electric charge. However, Salmon does not give us such an explanation. Moreover it is doubtful that he can find any difference between the relations that the two world lines respectively bear to electric charge. For, on the Humean empiricism to which Salmon wishes to be faithful, the relations seem to be essentially the same in that every spatiotemporally local region in each of the world lines has an electrical property. If so, even the revised argument does not help Salmon to disqualify w_2 from being a causal process.

5. Causal Interactions and Reconsideration of the Astrodome Example. In this section I first point out a problem for Dowe's and Salmon's definition of a causal interaction, (DCQ1) or (SCQ1); then I suggest a solution to the problem by modifying (DCQ1) in a way congenial to the spirit of CQ theory; finally, I argue that, given the modification, Salmon's response to the astrodome counterexample can be shown to fail even at a theoretical level.

Let us consider a metal plate where there is a boundary, one side of which has twice as much a uniform charge density as the other side. Suppose that a shadow moves across it in such a way that the area of the plate in shadow remains constant. Suppose further that the shadow passes from the side of low charge density to that of high charge density at about t_3. And let 'w_6' denote a time-wise gerrymandered world line of a series of patches that are in shadow, and 'w_7' denote a world line of a stationary patch that is in shadow just before t_3. The world lines, w_6 and w_7, are similar to w_2 and w_3 in Hitchcock's example, respectively. Is the intersection between w_6 and w_7 a causal interaction? Evidently no. Their intersection is just an overlapping of two world lines rather than a causal interaction.

(DCQ1) says that a causal interaction is an intersection of world lines that involves exchange of a conserved quantity. According to Dowe (1992, 210), "an exchange means that at least one incoming [process] and at least one outgoing process manifest a change in the value of the conserved quantity." But, the incoming part of w_6 possesses an amount Q of electric charge that is different from the amount 2Q of electric charge the outgoing part of w_6 possesses. Thus (DCQ1) seems to render the intersection as a case of a causal interaction. This poses a problem for (DCQ1).

It is likely that, in response to the problem, CQ theorists will supplement (DCQ1) with the requirement that the exchange should be "governed by the conservation law" (1992, 210). The requirement entails that the amount of electric charge in the total region occupied by w_6 and w_7 should be constant through the intersection. Before the intersection, the amount of electric charge in the total region is 2Q (the amount Q of electric charge possessed by the incoming part of w_6 + the amount Q of electric charge possessed by the incoming part of w_7). But, after the intersection, it is 3Q (the amount 2Q of electric charge possessed by the outgoing part of w_6 + the amount Q of electric charge possessed by the outgoing part of w_7). This means that the exchange is not governed by the conservation law. Therefore, the intersection is not a causal interaction. Thus it seems natural to suggest that "exchange" in (DCQ1) be understood to be governed by the conservation law.

As noted above, Salmon's response to the astrodome counterexample is based on the idea that there is a causal interaction between w_1 and a world line of a light ray at every stage of w_1 that involves an exchange of energy. But, there is no such causal interaction! Suppose 'E1' denotes an amount of energy a patch of wall possesses while it is being illuminated, and that 'E2' denotes an amount of energy a light ray possesses before intersecting with a patch of wall. Before the intersection between w_1 and the world line of the light ray, the amount of energy in the total region occupied by them is <E1 + E2>. On the other hand, it is E1 at the time of the intersection. This means that the intersection is not governed by the conservation law. In consequence, the intersection between w_1 and the world line of the light ray is disqualified from being a causal interaction by the modified definition of a causal interaction. Then Salmon's response to the astrodome example fails because there are no causal interactions between w_1 and the light rays. Of course, there is a series of causal interactions in the astrodome example that Salmon must have had in mind. However, each of them is not between w_1 and a world line of a light ray but between a world line of a stationary patch of wall and that of a light ray.

Since w_1 is a pseudo-process, Salmon's view that there is a series of causal interactions between w_1 and the light rays implies that even a pseudo-process can causally interact with other processes.[11] According to our intuition, however, only causal processes can causally interact with each other. The contention I made above satisfies this intuition.

I presume that, if Salmon had known what I stated above, then he would have attempted to disqualify w_1 from being a causal process on the ground of (P1*) as he did with Hitchcock's example.[12] For the amount of energy in the region of intersection, E1, does not equal the sum of the separate amounts of energy, $<$E1 + E2$>$. Then Salmon's responses to the two counterexamples would have had much in common. However, as we have seen, Salmon's response to Hitchcock's counterexample fails. Likewise his would-be response to the astrodome example also fails.

So far I have argued that Salmon does not succeed in handling two counterexamples against his CQ theory. One might object that Salmon can easily disqualify the gerrymandered world lines from being causal processes by requiring that a causal process be a world line of an object that maintains its identity over time. The gerrymandered world lines, w_1 and w_2, are not world lines that display identity over time. But this kind of response is not available to Salmon because he considers the concept of genidentity "highly problematic" (1997, 472).

6. Conclusion. I argued in the forgoing that Salmon's responses to the two counterexamples are unsatisfactory. I think Dowe's response to them is also unsatisfactory. The basic idea of Dowe's response is that a gerrymandered world line is not a world line of an object because "it does not display identity over time" (2000, 101). The world line does not qualify as a causal process because it does not satisfy (DCQ2), which requires that a causal process be a world line of an object. As Dowe has clearly declared, he assumes a notion of identity over time. Thus his response is in conflict with our belief that it is natural to analyze identity over time in terms of

11. The mark theory has the contrary implication that "if two processes intersect in a manner that qualifies as a causal interaction, we may conclude that both processes are causal" (Salmon 1984, 174).

12. An anonymous referee suggested this point.

causation rather than the other way around. Dowe goes on to reject this belief (104–107)—pace Dowe I think it is his CQ theory that must go.

Thus, in my opinion, neither Salmon nor Dowe provides a satisfactory response to the two counterexamples to CQ theory. I believe, however, that the search for a satisfactory response must be based on Salmon's insight that a causal process "transmits a conserved quantity." That will be a topic for another paper.

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