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ARE NECESSARY AND SUFFICIENT CONDITIONS CONVERSE RELATIONS?

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Claims that necessary and sufficient conditions are not converse relations are discussed, as well as the related claim that *If A, then B* is not equivalent to *A only if B*. The analysis of alleged counterexamples has shown, among other things, how necessary and sufficient conditions should be understood, especially in the case of causal conditions, and the importance of distinguishing sufficient-cause conditionals from necessary-cause conditionals. It is concluded that necessary and sufficient conditions, adequately interpreted, are converse relations in all cases.

I. Introduction

The purpose of this paper is to counter claims that necessary and sufficient conditions are not converse relations—claims, that is, that '*A* is a sufficient condition for *B*' is not the converse of '*B* is a necessary condition for *A*' [Wilson 1979; McCawley 1993; Sanford 2003; Brennan 2003]. In the context of this discussion, conditionals of the form *If A, then B* are taken to express that *A* is a sufficient condition for *B*, and those of the form *A only if B* to express that B is a necessary condition for A, at least within a certain set of circumstances.[1] If the relations are converse, then *If A, then B* and *A only if B* should be equivalent. This equivalence has likewise been challenged by the authors just cited and also by Lycan [2001].

Two relations R and R' are converses of each other if xRy is equivalent to $yR'x$ for all values of x and y [Russell 1937: 25]. Being a necessary condition is traditionally considered as the converse of being a sufficient condition. If the truth of *A* is sufficient for the truth of *B*, then the truth of *B* is necessary for the truth of *A* and vice versa. When the relation between *A* and *B* is

[1]One might question the assumption that conditionals involve necessary and sufficient conditions with the argument that most theories of conditionals have the consequence that '*A* & *B*' entails 'If *A*, then *B*', while the simple truth of *A* and *B* does not entail that *A* is a sufficient condition for *B*. For example, it is true that elephants are mammals and that London is the capital of England, but this does not entail that the former is a sufficient condition for the latter. It must be noted, however, that according to such theories, a conditional formed with these sentences must be considered true: '*If elephants are mammals, then London is the capital of England*'. My response, then, is that it is as counterintuitive to accept this conditional as true as it would be to accept that its antecedent is a sufficient condition for its consequent. Theories of conditionals are controversial and the consequence mentioned above should not be considered sufficient to invalidate the strong intuition that a conditional of the form 'If *A*, then *B*' implies that the truth of *A* is sufficient for the truth of *B*. The usefulness of analysing conditionals of the forms 'If *A*, then *B*' and '*A* only if *B*' in terms of necessary and sufficient conditions is exemplified in Varzi [2005] and Gomes [2006].

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logical, mathematical, or purely conceptual, there is no question about necessary and sufficient conditions being converse relations. For example, the truth of 'Bruno is an Italian pianist' is a sufficient (but not necessary) condition for the truth of 'Bruno is a pianist'. Conversely, the truth of 'Bruno is a pianist' is a necessary (but not sufficient) condition for the truth of 'Bruno is an Italian pianist'. In the form of conditional statements, we should have: 'If Bruno is an Italian pianist, then he is a pianist', equivalent to 'Bruno is an Italian pianist only if he is a pianist'.

There are cases, however, that have called into question this traditional conception [Wilson 1979; McCawley 1993; Lycan 2001; Sanford 2003; Brennan 2003]. It has been argued that examples like the ones discussed below show the failure of such a view. Contrary to these claims, it is argued here that, rather than demonstrating that necessary and sufficient conditions are not converse relations, these examples help to show how these relations should be understood. It will be seen that most of the anomalous cases involve causal, rather than logical, mathematical or purely conceptual relations.

The analysis of these examples has been fruitful. It has shown (1) the importance of distinguishing causal from non-causal conditionals and of distinguishing two types of causal conditionals (sufficient-cause conditionals and necessary-cause conditionals); (2) how to spell out the converse relations that hold in the case of causal conditionals; and (3) that necessary and sufficient conditions, adequately interpreted, are converse relations in all cases.

II. Sufficient Cause and Necessary Effect

Suppose that Jean tells Jack:

(1) If you touch me, I'will scream.

Although Jack's touching Jean appears as a sufficient condition for her screaming, Brennan [2003] claims that to take her screaming as a necessary condition for his touching her seems to get the dependencies back to front. This seems reasonable at first sight. Jack's touching Jean is sufficient to cause her screaming, but her screaming is not a necessary cause of his touching her. However, if we focus on the truth of the propositions, we shall see that the truth of the proposition that Jean will scream is necessary for the truth of the proposition that Jack touched her. This is because, if (1) is true, it cannot be the case that Jack touches her and she does not scream. The event described in *B* is not causally necessary for the event described in *A*, but the truth of *B* is necessary for the truth of *A*, as far as the event described in *A* is sufficient for producing the event described in *B*.

In a causal conditional such as (1), *A*'s being a sufficient condition for *B* means that *A* is a *sufficient cause* of *B*. We may read 'sufficient condition' (Jack's touching Jean) as 'sufficient cause', but we should not read 'necessary condition' (Jean's screaming) as 'necessary cause'. (This is what some commentators do when they say that Jean's screaming is not a necessary condition for Jack's touching her.) We should rather read it as 'necessary effect'. Indeed, if an effect of *A* is necessary, the truth of the proposition that affirms its occurrence (*B*) is a necessary condition for the truth of *A*. Thus, by understanding sufficient and necessary conditions, in this type of conditional, as *sufficient cause* and *necessary effect*, they are clearly recognized as converse relations. If *A* is a sufficient cause of *B*, *B* is a necessary effect of *A*.

Another important point to note is that in most cases, a cause is sufficient to produce an effect only within a certain range of circumstances. Accordingly, a causal conditional such as (1) may apply only in a certain context. We can easily imagine circumstances in which Jill would not scream even if Jack touched her, but the conditional is not meant to apply to such circumstances.

Consider the following example by Sanford [2003: 175]:

(2) If you learn to play the cello, I'll buy you a cello.

Sanford argues that, in this case, you cannot use '*A* only if *B*' as equivalent to 'If *A*, then *B*', since you would get:

(3) You will learn to play the cello only if I buy you a cello.

This would have a rather different meaning from (2), since it implies that your learning depends on my buying you the instrument, while in (2) it is the other way round. In fact, the transformation of the sentence to the equivalent '*A* only if *B*' form *is* possible. We could say, without any change in meaning: 'It will be true that you have learned to play the cello only if, at that moment, it is also true that I'll buy you a cello.' Some adaptations were made to preserve the temporal and causal sequence, but the content and meaning of the conditional were maintained, even if in a clumsy form.

What we find is that in (1) and (2) the tenses of the verbs used (present, future) fix a certain temporal (and causal) sequence between *A* and *B*, and the 'only if' formulation of the conditional may misleadingly imply an inversion of this sequence. In causal terms, if we understand (2) as meaning 'Your learning to play will be a sufficient cause of my buying you a cello', the converse would be: 'My buying you a cello will be a necessary effect of your learning to play'.

A similar example, from McCawley [1993: 82], is:

(4) If butter is heated, it melts.

McCawley contends that the meaning seems reversed if we change it to 'Butter is heated only if it melts'. It seems to me, however, that this sentence *may* also be understood in the right sense. It would become clearer by changing the tense: 'Butter has been heated only if it melts.' (The cause precedes the necessary effect.)

Another example:

(5) If John wins the race, we'll celebrate.

Our celebrating is a necessary condition in the sense that it is a necessary effect of John's victory. (Note that 'condition' is used here in a broad sense and not in the sense of a causal factor.) The truth of the proposition that affirms that we shall celebrate is necessary for the truth of John's winning the race, if (4) is true.

Lycan (2001: 29, 38) gives the following two counterexamples to the equivalence between *If A, then B* and *A only if B*:

(6) If I leave, then Joe will leave.
(7) If Gore is nominated for President, I will skip the front page of my newspaper.

He notes that we would get completely different meanings with:

(8) I will leave only if Joe leaves.
(9) Gore will be nominated for President only if I skip the front page of my newspaper.

[Lycan 2001: 39–40]

However, resources similar to those we applied to (2) will show that it is possible to give acceptable, though clumsy, *A only if B* equivalents for (6) and (7): 'It will be the case that I have left only if it will also be the case that Joe will leave' and 'It will be the case that Gore has been nominated for President only if it will also be the case that I will skip the front page of my newspaper'. Joe's leaving and the speaker's skipping the front page of his newspaper will be the necessary effects of the antecedents of (6) and (7), respectively.

III. Sufficient Effect and Necessary Cause

The following example by McCawley [1993: 82] involves the opposite transformation (from '*A* only if *B*' to 'If *A*, then *B*'):

(10) My pulse goes above 100 only if I do heavy exercise.

We get the opposite temporal and causal relation with 'If my pulse goes above 100, I do heavy exercise.' However, the same small change from present tense to present perfect would make things right again:

(11) If my pulse goes above 100, I have done heavy exercise.[2]

[2]This is similar to the following attested example: 'As producers, it is our job to create this [flawless singer performance that is what the public wants to buy], and if much of our work goes by unnoticed, then we have done our job well' (Robert Holsman, retrieved March 12, 2008 from <www.record-producer.com/learn.cfm?a = 4233>).

Here we have a different kind of causal conditional. Instead of *A* being a sufficient cause and *B* a necessary effect, *B* (having done heavy exercise) is a necessary cause of *A*. According to (10), no other condition can make my pulse go above 100. What is *A* in this case? It is, for sure, an effect of *B*. Moreover, the notion of sufficiency is certainly present in relation to *A* and shows itself clearly in the transformed version 'If my pulse goes above 100, I have done heavy exercise'. The truth of the proposition that affirms that my pulse has gone above 100 is sufficient for the truth of the proposition that affirms that I have done heavy exercise. Thus, we have reason to introduce what seems to be a new concept and say that *A* is in this case a *sufficient effect* of *B*.[3]

Again, it is important to note that a cause may be necessary to produce an effect only within a certain range of circumstances. In exceptional circumstances, the effect might be produced by a different cause. The person who states (10) or (11) certainly means that, *in usual circumstances*, her pulse goes above 100 only if she does heavy exercise. This does not exclude that an adrenaline injection might also produce this effect in the absence of any exercise.

In the following two examples, the same change from '*A* only if *B*' to 'If *A*, then *B*' requires the use of the future perfect in the consequent to preserve the temporal and causal sequence (and the future in the main clause of (12) must be changed to the present in the *if*-clause of (13)).

(12) [I was at the shop Saturday morning and I could see there is still a lot to be done.] It will be open by Monday only if someone does a lot of work over the weekend.

(13) If it is open by Monday, someone will have done a lot of work over the weekend.

In (13), the consequent (someone having done a lot of work over the weekend) is a necessary condition for the antecedent (the shop being open by Monday) and the latter a sufficient effect of the former. (The fact that is not also a necessary effect is shown by the consideration that even if someone does a lot of work over the weekend it may still be impossible to open the shop by Monday.)

A sufficient effect of *B* is an event that only occurs as a result of a previous occurrence of *B*, though *B* may also occur without being followed by this effect (if *B* is not also a sufficient cause of it). From an epistemic point of view, the occurrence of such an effect is *sufficient evidence* of the occurrence of its cause (this corresponds to what Brennan calls a reason for thinking, as opposed to a reason why [Brennan 2003; Goldstein et al. 2005]).

While the causal conditionals in §II may be called *sufficient-cause conditionals*, those such as (11) and (13) may be called *necessary-cause conditionals*. Another example of a necessary-cause conditional is:

(14) If she made that remark, she knew about his past.

[3]Not in the sense of an effect that is sufficient for something else, but in the sense of one that is sufficient for its cause, meaning that the truth of the proposition that affirms its occurrence is sufficient for the truth of the proposition that affirms the occurrence of its cause.

Knowing about his past was a cause of her making the remark. It helped produce this event. Moreover, the speaker is considering this as a necessary cause of her remark, since he or she can envisage no circumstance in which the woman would have made it without knowing the relevant facts about the man's past.

From an epistemic point of view, her having made the remark is sufficient evidence for the speaker to infer that she knew about his past. Note that in a sufficient-cause conditional, the speaker infers an effect from its cause. Here, in contrast, the speaker does not infer that the remark was made from the fact that the woman knew about the man's past. On the contrary, this is the fact that he infers, from its effect. For the speaker, her having made the remark is sufficient evidence of her knowing about his past.

Thus, a fundamental difference between sufficient-cause and necessary-cause conditionals is that, in the former, the direction of inference is the same as the direction of causality (from A to B), while in the latter, the direction of inference (from A to B) is opposite to the direction of causality (from B to A). Inference in the latter does not follow the sequence of the events or states denoted by the conditional.

IV. Logical Conditionals and Causal Conditionals

Logical conditionals and causal conditionals have the same structure. Both exclude the conjunction of A with $\sim B$. However, while in logical conditionals there is a logical reason for this exclusion, in causal conditionals there is no logical incompatibility between A and $\sim B$. In the latter, the sufficiency of A for B depends on additional facts and causal dependencies.

Logical conditionals are what Bennett called 'independent conditionals', since in them 'one can get the consequent from the antecedent without input from any matters of particular fact' [Bennett 2003: 16]. According to him, causal conditionals may also be independent. He gives the following example:

(15) If the dinghy and its contents come to weigh more than the same volume of the water they are floating in, the dinghy will sink.

Another passage of his own book suggests an objection: Not if the dinghy is attached to a balloon. (We could also imagine other conditions in which this dinghy would not sink—for example, if the water were very shallow.) Thus, causal conditionals seem always (or almost always) to depend on unstated matters of particular fact—and thus never to be really 'independent' conditionals.

This means that the sufficiency of A for B and the necessity of B for A is absolute only in logical conditionals. In causal conditionals, it is only relative. It is only in the context of certain unstated conditions that A is sufficient for B and B necessary for A. In logical conditionals, *A implies B*. In colloquial language, this verb may also be used in relation to causal conditionals, but in philosophical usage one may wish to reserve it for *logical* implication. Regarding causal conditionals, instead of saying that *A* implies *B*, one could say that *A permits us to infer B*, *in a given context*.

We should also make clear that 'necessary cause', in relation to causal conditionals, refers to an event or state (B) that is necessarily at the origin of another (A) (in the context considered). However, if this cause is not also sufficient, it does not necessarily give rise to A. In contrast, 'sufficient cause' refers to an event or state (A) that necessarily gives rise to another (B) (in the context considered), although the latter may also occur from different causes (if the former is not also a necessary cause). Sometimes, 'necessary cause' is used in a different sense, meaning 'necessarily existing cause'. It is in this sense—which is not contrasted with 'sufficient cause'—that Hobbes maintains that there is a 'necessary cause' for everything (not excluding that in some cases the same event may result from different causes) [Hobbes & Bramhall 1999]. 'Necessary cause' is also used to refer to God, as the ultimate cause of all beings (Aristotle, Leibniz, etc.).

Thus, in sufficient-cause conditionals, the occurrence of the cause permits us to infer the occurrence of the effect, in a given context. In necessary-cause conditionals, in contrast, the occurrence of the effect, in a given context, permits us to infer the previous occurrence of the cause.

V. Necessary and Sufficient Causes

Colloquially, it might be understood in (5) ('If John wins the race, we'll celebrate') that we are specifically talking about celebrating John's victory. Accordingly, one might understand (5) as implying that if John does not win the race, we shall not celebrate (his victory). In this case, we should have here a necessary and sufficient condition.[4] This becomes even more evident if we change (5) to:

(16) If John wins the race, we'll celebrate his victory.

We could not celebrate his victory if he does not win, so it seems that his winning the race is a sufficient *and necessary* cause for our celebrating his victory. *If* could be replaced here by *if and only if*:

(17) If (and only if) John wins the race, we'll celebrate his victory.

This interpretation of *if* as *iff* has been discussed by several authors [e.g., Ducrot 1969; Geis and Zwicky 1971; van der Auwera 1997a and b; Horn 2000; Jaszczolt 2005: 216–18] and has been called *conditional perfection*. It is a matter of debate how it should be explained. Most authors see it as a conversational implicature [Comrie 1986; Sweetser 1990; van der Auwera 1997a and b; Horn 2000]. Ducrot [1969] sees it as a case of *sous-entendu*, a concept very similar to the Gricean concept of conversational implicature

[4]Alternatively, one may understand that we are talking about celebrating in general, for whatever reason. Even if John does not win, we might celebrate Mary's return, for example. In this case, (5) would be specifying only a sufficient (but not necessary) condition.

[Horn 2000: 311]. Geis and Zwicky [1971] consider it as an 'invited inference'. Although they emphasize that the inference may very well be wrong (and relate it to the classical logical fallacies of Denying the Antecedent and Affirming the Consequent), they consider it as a general tendency [1971: 562]. Subsequent work has shown, however, that in many cases no such tendency is present [Lilje 1972; Boër & Lycan 1973].

It is beyond the scope of this paper to try to explain when and why conditional 'perfection' of *if* to *iff* is present or absent. It may be remarked, however, that in cases such as (16) the antecedent is a presupposition of the consequent: as remarked above, we can only celebrate John's victory in the race if he wins the race. Consequently, if John does not win the race, we will not celebrate his victory in the race. The biconditional is a consequence of the fact that the consequent presupposes the antecedent.[5]

'Perfection' of *only if* to *iff* has not received as much attention, but Lycan [2001: 37, n. 24] goes so far as to say:

> I believe ... that in colloquial English 'P only if Q' carries a similar implication, whether entailment or pragmatic; 'I will pass you only if you get an A on the final' implies that I will pass you *if* you get an A on the final .... I surmise that at some point 'only if' acquired a technical use in mathematics ... that permits the otherwise redundant 'if and only if' (compare 'Susan and only Susan') and that this technical use has filtered into ordinary academic English ...

However, the *if* implicature in *only if* sentences is far from being that general. Even in Lycan's example, the addressee may already know that that in order to pass she must also satisfy some other condition, such as attending a seminar or turning her homework in. Thus, getting an A on the final may be a necessary but not sufficient condition for passing.

The biconditional interpretation is also natural in relation to (4), which could be rephrased as:

(18) Butter melts if and only if it is heated.

According to McCawley [1993: 87], ' ... the expression *if and only if* is asymmetric, that is, ... *A if and only if B* is not interchangeable with *B if and only if A* ... '. We may agree with the asymmetry if we interchange the exact linguistic expressions and say: 'Butter is heated if and only if it melts'. However, we have already seen that a change in tense would put things in order:

(19) Butter melts if and only if it has been heated.

This improved version is indeed symmetric:

(20) Butter has been heated if and only if it melts.

[5]In a related but different connection, von Fintel [1999] has shown the importance of the presuppositions of the consequent in conditionals.

This symmetry derives from the convertibility of the two component relations: *A* if *B* (*B* sufficient) is the converse of *B* only if *A* (*A* necessary) and *A* only if *B* (*B* necessary) is the converse of *B* if *A* (*A* sufficient). Heating butter being the sufficient cause of butter's melting is the converse of butter's melting being the necessary effect of heating butter. Heating butter being the necessary cause of butter's melting is the converse of butter's melting being the sufficient effect of heating butter. Of course, we are admitting, for this conditional to be true, a certain initial temperature and a certain degree of heating.

A suitable converse of (17) would be:

(21) If and only if we celebrate John's victory will it be true that he has won the race.

This would convey that if we do not celebrate, you can be sure that he has not won. From an epistemic point of view, our celebrating will be sufficient evidence of his winning. From a causal point of view, it will be a sufficient effect of his winning, as defined above, as well as a necessary effect, in the context intended by the speaker. Conversely, his winning will be a necessary and sufficient cause of our celebrating his victory (in the same context).

Another example of a necessary and sufficient causal relation between *A* and *B*:

(22) One's heart's ceasing to function is a necessary and sufficient cause of one's blood's ceasing to circulate.[6]

The converse of this would be:

(23) One's blood's ceasing to circulate is a necessary and sufficient effect of one's heart's having ceased to function.

The two conditionals involved would be:

(24) If his heart ceased functioning, his blood ceased circulating.
(25) If his blood ceased circulating, his heart had ceased functioning.[7]

The 'only if' versions of these would then be:

(26) It is true that his heart ceased functioning only if it is also true that his blood ceased circulating.
(27) His blood ceased circulating only if his heart had ceased functioning.

[6]Heart transplant conditions excluded.
[7]Future time versions of these would be: 'If his heart stops functioning, his blood will stop circulating' and 'If his blood stops circulating, his heart will have stopped functioning'.

VI. Other Kinds of Conditionals

Some conditionals are neither purely logical, nor mathematical, nor conceptual nor causal. Consider Lewis's [1973: 3] famous example (based on Adams [1970]):

(28) If Oswald didn't kill Kennedy, then someone else did.

Pure logic does not make *A* a sufficient condition for *B*. *A* is not the cause of *B*, nor is *B* the cause of *A*. In order to accept that the truth of *A* permits us to infer the truth of *B*, we need to know the facts (not mentioned in the conditional) that Kennedy was killed by bullets that must have come from a gun that must have been fired by someone. Then pure logic allows us to conclude that if that person was not Oswald, it was someone else. Conditionals of this kind may be called *non-causal empirical conditionals*, to distinguish them from non-causal logical, mathematical or conceptual conditionals. (Obviously, their justification also involves causal and logical relations.)[8]

Another example:

(29) If Lilly was late to work, Bob was late too.

Again, *A* did not cause *B* nor did *B* cause *A*. Additional facts are needed to justify the conditional. For example, it may be that Lilly and Bob took the same train and it is certain that they went directly from the train station to their work, which is just in front of the station. So if one was late, that is because the train was late and consequently the other was late too. If so, *A* is, in this context, a sufficient effect of X and X a sufficient cause of *B* (X being the fact that the train was late). Since causality proceeds from the same cause to two different effects, Bennett [2003: 339] characterizes these conditionals as 'V-shaped'. They are justified by two causal relations with an unstated fact: *A* has a necessary cause which, in its turn, is a sufficient cause of *B*, in the context considered. We may thus call them *unstated-cause V-shaped conditionals*.

An interesting example, modelled on Wilson [1979], is given by Brennan [2003]:

(30) If Lambert was present, it was a good seminar.

This may be meant or understood in the sense that Lambert's active participation caused the seminar to be good. However, it may also be meant or understood according to the same model of (29). For example, Lambert's presence may be evidence that intelligent, communicative and well-informed people were scheduled to participate in this seminar, because he only goes to seminars like this. With such participants, the seminar was bound to be

[8]In a special context, (28) could be meant as a causal conditional. Suppose the assassination was the result of a conspiracy. As Bennett [1995: 335] remarks, (28) could have been stated, after the scheduled time of the attack, by a conspirator who believed that if Oswald had failed someone else would have taken on the job.

good. Thus, we may consider this conditional as *indeterminate*, in the sense that it is not obvious whether there is a direct causal relation between *A* and *B* or a V-shaped causal relation of both with an unstated cause.

One might say that (30) merely states that from Lambert's presence we may infer that the seminar was good and that it tells us nothing about what caused the seminar to be good. However, in ordinary language, such a conditional would normally be meant and understood either as a sufficient-cause conditional, in which the antecedent is a sufficient cause of the consequent, or as an unstated-cause V-shaped conditional, in which the antecedent is a sufficient effect of some fact which, in its turn, is a sufficient cause of the consequent.

VII. Conclusion

We arrive at the following conclusions: *A* is a sufficient condition for *B* and *B* is a necessary condition for *A* if *A* implies or permits us to infer *B*. *A* is a sufficient cause of *B* and *B* is a necessary effect of *A* if *A* both causes and permits us to infer *B*. *B* is a necessary cause of *A* and *A* is a sufficient effect of *B* if both *B* causes *A* and *A* permits us to infer *B*.

To avoid possible misunderstandings, let me make clear that these statements are not intended as definitions. Thus, it is not being claimed, for example, that it is only if *A* permits us to infer *B* (in addition to being a cause of *B*) that *A* is a sufficient cause of *B*. What we are permitted to infer depends on our knowledge, and of course there may be sufficient causes of which we know nothing. Nor does the statement about sufficient causes above assume that all causes are sufficient causes. It is if *A* both causes and permits us to infer *B* that it qualifies as a sufficient cause. *A* may be a cause of *B* in some cases and fail to be a cause of *B* in others and in this event it is not a sufficient cause. However, if *A* is a cause of *B* and the occurrence of *A* permits us to infer the occurrence of *B*, then it may not be the case that *A* in some cases fails to cause *B*.

Conditionals involving necessary conditions and sufficient conditions may be seen, in general, as corresponding to the form:

(a) If (sufficient condition), then (necessary condition).

Or, equivalently:

(b) (Sufficient condition) only if (necessary condition).

In other words, they may be considered as corresponding to the form *If A, then B*, or equivalently, to the form *A only if B*, where the truth of *A* is sufficient for the truth of *B* and the truth of *B* is necessary for the truth of *A*, in the context considered.

This implies that:

(c) If (necessary condition) is not the case, then (sufficient condition) is not the case either.

Stated differently, we may say 'If $\sim B$, then $\sim A$', where the falsity of a necessary condition for A (i.e., of B) is sufficient for the falsity of A and the falsity of a sufficient condition for B (i.e., of A) is necessary for the falsity of B.[9]

Causal conditionals are special cases of the former and may be considered as corresponding to one of the following two forms:

(d) If (sufficient cause), then (necessary effect).
(e) If (sufficient effect), then (necessary cause).

In other words, they may be seen as corresponding to the form *If A, then B*, where either (d) A is a sufficient cause of B and B is a necessary effect of A, or (e) A is a sufficient effect of B and B is a necessary cause of A. Directions of causality and of inference are identical in (d) and opposite in (e).

These imply, respectively, that:

(f) If (necessary effect) does not occur ($\sim B$), then (sufficient cause) has not (previously) occurred either ($\sim A$).
(g) If (necessary cause) has not occurred ($\sim B$), then (sufficient effect) does not occur either ($\sim A$).

In (f) the non-occurrence of a necessary effect of A (i.e., of B) is a sufficient effect of the previous non-occurrence of A,[10] and the non-occurrence of a sufficient cause of B (i.e., of A) is a necessary cause of the non-occurrence of B. In (g) the non-occurrence of a necessary cause of A (i.e., of B) is a sufficient cause of the non-occurrence of A, and the non-occurrence of a sufficient effect of B (i.e., of A) is a necessary effect of the non-occurrence of B.

Thus, a necessary condition may be necessary cause or necessary effect (or neither), while a sufficient condition may be sufficient cause or sufficient effect (or neither). A's being a sufficient condition for B implies that B is a necessary condition for A, but A's being a *sufficient cause* of B does not imply that B is a necessary cause of A, but rather that it is a *necessary effect* of A. While B's being a *necessary cause* of A implies that A is *a sufficient effect* of B, in the sense that it only occurs when B has occurred. In every case necessary conditions and sufficient conditions are converse relations.

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[9] Conditionals for which contraposition fails, which I call atypical [Gomes 2008], do not involve necessary and sufficient conditions.

[10] From an epistemic point of view, it is sufficient evidence of the previous non-occurrence of A (or a reason for thinking that A did not previously occur [Brennan 2003; Goldstein et al. 2005]).

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