The Causal Relation: Salmon's Attempt to Solve Hume's Problem

Kyle Staub
University of Colorado Boulder

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Salmon’s Attempt to Solve Hume’s Problem

Kyle Staub

University of Colorado at Boulder
Department of Philosophy

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Advisor:
Jason Potter, Department of Philosophy

Committee:
Wes Morriston, Department of Philosophy
Jason Potter, Department of Philosophy
Greg Johnson, Department of Religious Studies
ABSTRACT

This work presents a historically accurate and robust account of David Hume’s problem of causation, providing sufficient detail about the aspects of his account which are most relevant to the discussion of causation in general. This interpretation of Hume’s problem focuses on the unjustified idea of the causal relation in which the cause necessitates the effect. Secondly, I present the development of Wesley Salmon’s process theory, from his 1984 work Scientific Explanation and the Causal Structure of the World, to his acceptance of Phil Dowe’s conserved quantity theory. I examine both accounts in detail, and present my own objection to Salmon’s central criterion of the process theory, the Mark Transmission principle. From there, I import Salmon’s version of the conserved quantity theory into the Humean framework and challenge his assertion that he has solved Hume’s problem of causation. The conserved quantity theory fails to solve Hume’s problem, in that it is essentially a process-based regularity theory, which relies on observed changes across interactions, without proposing any causal force to the interaction itself. Without any causal force inherent in the interaction which necessitates the effect, given the cause, the conserved quantity theory explicitly aligns itself with the Humean interpretation of the causal relation, lacking the psychological components.
I. Introduction

Our idea of causation seems to be one of the most important concepts in our daily lives. It allows us to interpret and understand the world. We are intimately familiar with causation, even if its metaphysical complications are not evident to us. The window broke because the ball hit it. The coffee spilled because I knocked it over. The basement flooded because of the rain. Each of these examples contains the word “because”, indicating a causal relationship between the referents of the two clauses. Effect because Cause. To say that something causes another thing is to posit a relationship between them, a relationship of dependence or connection such that the cause somehow brings about the effect.

The philosophical need to establish the precise nature of the relationship between what we call cause and effect is the central focus of this work. David Hume, in A Treatise of Human Nature, examines the causal relation under the empiricist framework, and finds it lacking the proper origins. For Hume, all ideas must originate in original impressions (or what is presented to conscious awareness), of which there are three kinds: sensation, reflection, and emotion. Hume’s project is psychological, in that the focus is on one’s mental content, and not entities as they exist objectively in the external world. Returning to the causal relation, Hume identifies four essential aspects which are necessary for the formation of the idea of a causal relation, as it has been understood by philosophers until now. These four aspects are resemblance, succession in time, spatio-temporal contiguity, and necessary connection. Of these four aspects, the necessary connection between cause and effect cannot be justified based on either of the two types of claims one is capable of making (‘relations of ideas’ or ‘matters of fact’ claims). Our concept of a necessitating causal relation must therefore be an artifact of our psychology and, as Hume says, “necessity is nothing but that determination of the thought to pass from causes to effects, and
effects to causes, according to their experienced union” (Hume, 1739, pp.92). Thus, assumptions of causal relations are merely powerful associative links in thought, such that thoughts of events of one type elicit thoughts of events of another type, and those two types of events are considered to be cause and effect. This associative link is formed through an observed constant conjunction between types of events, impressing upon one’s memory their resemblance, spatio-temporal contiguity, and that same constant conjunction.

Modern-day metaphysicians who are persuaded by Hume’s reasoning about causation are known as “regularity theorists”, and their explanations of so-called causal phenomenon are often cached out in statistical regularities, sufficient conditions, etc. This work does not go in-depth about the variety of regularity theories, but rather focuses on a proposed alternative to regularity theories – Wesley Salmon’s process-based account of causation.

Salmon’s initial account included a criterion for distinguishing causal processes from pseudo-processes, the Mark Transmission Principle. This principle is the source of a major objection that renders Salmon’s initial account incapable of distinguishing causal processes from pseudo-processes. For related concerns, Phil Dowe radically altered Salmon’s original theory into the conserved quantity theory in a paper published in 1992. The conserved quantity theory still takes processes to be the relata of the causal relation, but explains causal interactions in terms of exchanges of conserved quantities. These conserved quantities are those quantities which, in a closed system, maintain a constant value across an interaction. Some familiar examples of these quantities are linear momentum, mass/energy, charge, etc. Salmon adopts this approach in 1994, making slight alterations.

Since 1984, Salmon has maintained that processes “constitute precisely the objective physical causal connections which Hume sought in vain” (Salmon, 1994, pp. 297). To see if
Salmon has actually solved Hume’s problem of causation, I will examine the conserved quantity theory within a Humean framework, attempting to account for all of the ideas utilized by Salmon in terms of impressions of sensation, reflection, or emotion. In such a framework, all such ideas are indeed accounted for, however the theory does not solve Hume’s problem – in fact, it reinforces Hume’s conclusion. Causal processes are meant to causally interact by exchanging some amount of a conserved quantity across that interaction. The term “exchange”, according to the conserved quantity theory, means that at least one incoming and at least one outgoing process manifests a change in the value of a conserved quantity. This notion of “exchange” is highly empirical, but does not provide the necessitating feature of the causal relation which is required to “solve” Hume’s problem. Instead, this sense of “exchange” reaffirms that so-called causal relations are no more than constantly observed conjunction of changes in the impressions of the relata, making the conserved quantity theory a process-based regularity theory. The conserved quantity theory certainly has its advantages over other regularity theories, but does not satisfy the conditions required by Hume to establish that causation, understood as a necessitating relation, is an objective feature of the world.
II. CAUSATION AND HUME’S PROBLEM

HUME ON THE ORIGIN OF IDEAS

David Hume, in *A Treatise of Human Nature* (orig. 1739), puts forth an empiricist account that explains the origins of all of our mental content, or that part of the latter he calls ‘ideas’. This account is lengthy and complex, and not all of the details are essential to this discussion of causation. I will give a succinct summary of the relevant aspects here. Coming from an empiricist framework in the philosophy of mind, Hume believes that all of one’s mental content must come from the original content of consciousness, or what he calls ‘impressions’. These impressions can be split into three categories – impressions of sensation, impressions of reflection, and impressions of emotion. Impressions of sensation are those contents of awareness arising due to the action of our perceptual faculties, impressions of reflection are those arising from the operations of the mind itself, and impressions of emotion are those arising from emotional mental states. A further distinction that Hume makes is between impressions and ideas. Impressions are the source of all ideas, and ideas, as Xerox-like copies of impressions, are the “faint images of [impressions] in thinking and reasoning” (Hume 1739, pp. 1). Ideas, then, are the mental contents that are generated by the copying of original impressions of sensation, reflection, or emotion, all of which are subsequently stored in memory.

Ideas and impressions are further separated into two classes – simple and complex. Simple ideas or impressions are “such as to admit of no distinction nor separation” (Hume 1739, pp. 1). Additionally, simple ideas are always exact copies of the impressions that they originated from. For instance, the idea of a particular shade of red cannot differ (in nature) from the original impression of that shade of red. Simple ideas, then, bear reference to only one distinct
impression, which cannot be further broken down into separate, original components. The shade of red mentioned cannot be further separated into shape, or size, etc. as that would mean the idea was complex to begin with. Complex ideas, on the other hand, are composed of two or more simple ideas, and are not always exact copies of complex impressions. In fact, there may not exist any impression that corresponds to some complex ideas.

The faculties of the mind that operate on or with ideas, according to Hume, are the memory, imagination, and reason (intellect). The memory brings forth ideas to the mind, and preserves their original form as impressions, though the ideas lack the vivacity of the original impressions to which they correspond. The imagination has two forms, one passive, and one active. The active form is capable of combining ideas into complex ideas, the passive form is responsible for creating the associations among ideas stored in memory that provide the basis for the generation of concepts by means of abstraction. The intellect/reason allows the mind to analyze/decompose complex ideas into simpler ones, and to perform the act of abstraction by means of which concepts are formed. For instance, it can take the complex idea of a big red ball and decompose the idea into its constituent simple property concepts – its size (big), its shape (round and ball-like), and its color (red). The imagination can recombine these simple property concepts with others to create the complex idea of a big blue cube

Hume describes how the passive imagination creates the associative links between incoming impressions and each other, or an impression with existing ideas stored in memory, such that the thought of one always elicits thought of the other, or vice versa. There are four features of the incoming, original impressions on the basis of which the subsequently stored ideas are associated with one another by automatic action of the passive imagination: (1) their

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1 The imagination is not the only source of a complex idea of a big blue cube, but it is capable of creating such an idea through the process described.
resemblance to each other, (2) their contiguity in time-of-arrival in awareness, (3) their contiguity in space, or (4) their relationship of cause and effect (which for Hume is their constant conjunction in experience). Of these, Hume claims that the relation which produces the strongest association between two ideas is that of cause and effect. Two objects\(^2\) are considered to be in this relation not only when one is the “cause of any of the actions or motions of the other” but also when one is the “cause of the existence” of the other (Hume, 1739, pp.6). The passive imagination most-strongly associates ideas that bear all of these four relations to one another, making them inseparable in the memory. Concepts are generated based on these associations by a process of abstraction that is no different in Hume’s account of the origin of all ideas than in John Locke’s: they arise the mind’s ability to note similarities among its ideas and to generate a common representation that stands for anything that resembles them in the respect in which the mind noticed their similarity.

This framework accounts for all of our ideas: simple, complex, and general, and provides an exhaustive dichotomy between the types of judgments/assertions one can make on the basis of these ideas: “relations of ideas” judgments, and “matters of fact” judgments. A relation of ideas claim is one which depends solely on the ideas involved and, based on their meaning or definition, a claim can be determined to be either true or false. These claims are essentially a priori, and are justifiable independent of any particular sense impression. For instance, the claim “all bachelors are unmarried males” is a relation of ideas claim, because the definition of “bachelor” simply is “unmarried male”. In thinking the subject concept, one is unavoidably thinking the predicate concept, and thus, there is a containment relation between subject and predicate that secures the truth of the claim, and it is this kind of relation that leads Hume to refer

\(^2\) Hume uses objects as the relata of the causal relation, and in writing from a Humean perspective, I will as well.
to this type of judgment as a ‘relation of ideas’ type. Therefore, the claim being evaluated has a truth value which is solely dependent on the nature of the ideas contained therein (e.g. “bachelor” and “unmarried male”) and their relation in thought. In contrast, a matter of fact claim is essentially *a posteriori*, or dependent on particular impressions of sensation, reflection, or emotion. A matter of fact claim’s truth is determined by the way the world is presented to the faculties of sense. For instance, take the matter of fact claim “this ball is red”. This claim refers to a specific object in the world, namely ‘this ball’, and requires an empirical observation by way of perception (of sight or touch) to confirm or deny. If the impressions of sensation associated with the ball, and from which its concept is constructed, are conjoined in the same perception with impressions of sensation associated with the concept ‘red’, the claim is true; otherwise, it is false.

These two types of claims – relations of ideas and matter of fact – are the only kinds of claims one is capable of making, because they encapsulate the possible ways that the relations between subject and predicate in a judgment can be grounded: either by definition/conceptual containment, or by the conjoined impressions of sensation, reflection and/or emotion that display the relation asserted in the judgment. Either our ideas have their origin and basis in analytic relations among ideas we already have, or they have their origin and ground in impressions of sensation, reflection, or emotion.

**Hume on Causation**

Having given a brief summary of Hume’s project and his account of the origins of our ideas, we can now focus specifically on Hume’s view of causation. As mentioned above, the relation of cause and effect between two objects implies and creates a powerful association
among the ideas involved. However, the notion of what it means for one thing to cause another has yet to be examined, and was largely taken for granted in metaphysics before Hume examined them in his *Treatise of Human Nature*.

In that work, Hume is searching for the origin of our complex idea of a causal relation. Before that search can commence, Hume provides a more clear analysis of what concept is meant by the word “causation”. First, causation must be considered as a relation between objects, as there is nothing that exists which could not be considered either as a cause or as an effect, and there is no inherent quality of objects which designates them as cause or effect. Thus, causation is a relation between objects, and pertains to a specific manner in which they are related. This relation must have, among other things, the feature of contiguity of both space and time. Distinct objects, which are separated by too much distance in space or time, cannot bear a causal relation to one another. Furthermore, causes must be prior to their effects in time. That is to say, an effect cannot be simultaneous with its cause, nor can an effect occur prior to its cause. Finally, there must be a necessary connection between a cause and its effect. This necessary connection between cause and effect seems to be a necessary condition required of any two objects that are related as cause and effect, because continuity and temporal priority are not sufficient to establish a causal relationship. It is not merely that a cause is temporally prior to and spatiotemporally contiguous with its effect, there must be something about the cause which forces the effect to come about.

Within the framework provided by Hume, it is clear that the idea of a causal relation must have its origins in a logical dependency between the idea of an effect and the idea of its cause, or in impressions of sensation, reflection, or emotion that present to the occurrent consciousness, unless connected by a “chain of causes, which are contiguous among themselves, and to the distant objects”.

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3 Unless connected by a “chain of causes, which are contiguous among themselves, and to the distant objects”.
now or in the past, everything present in the idea of that relation (namely: temporal and spatial contiguity, temporal priority of cause, resemblance of cause and effect, and necessary connection between cause and effect). Let us begin by examining a general claim: “C causes E”. For this to be a ‘relation of ideas’ claim, there must be something about the very ideas of “C”, “causes”, and “E” which make this statement true or false. There is nothing about the concepts associated with “C” and “E” which connect them analytically, definitionally, and hence necessarily (unlike ‘bachelor’ and ‘unmarried male’, for example). There is nothing about their qualities, definitions, or meanings such that the thought of one necessarily leads one to the thought of the other. It cannot be in the concept of “cause” either, because for any particular instance of an observed cause and effect relationship, one can imagine that the effect is different. For instance, C could cause the opposite of E, or something entirely unrelated to E, or E could arise in an entirely different fashion. This means that there is no relation of logical dependency that requires E, given that C. For instance, suppose there are two billiard balls on a table. One ball (call it C) is approaching the other ball (call it E) at a slight angle. Picturing this situation in your mind’s eye, imagine that when ball C strikes ball E, ball E goes in an unexpected direction (i.e. not what you would expect, given the angle of the strike). This simple thought experiment makes clear that causes do not necessitate their effects, or that it is logically possible for the effect not to occur. Because the relation of causation lacks this logical entailment, the claim “C causes E” cannot be a relation of ideas claim.

The other type of claim that “C causes E” could be is a matter of fact claim. For “C causes E” to be a matter of fact claim, there must be something in one’s impressions that reveals the necessity of E, given that C. However, there is no such impression. No impression reveals anything beyond ball C approaching ball E at a certain velocity, the sound of the collision, and
the velocity of balls C and E following the collision. There is nothing in one’s impressions of sensation associated with the motion of ball C that presents it “reaching out” or “forcing” the impressions of sensation associated with the motion of ball E. However, there are impressions of sensation which correspond to the other three features of the causal relation (resemblance, temporal priority, and spatio-temporal contiguity). There are simply impressions of sensations associated with each ball, but no impression of their necessary connection. Therefore, the claim “C causes E” is not a matter of fact claim, either.

This conclusion is troubling to Hume, because there appears to be a complex idea of a causal relationship, which cannot constitute an analytical relationship between the idea of cause and the idea of its effect, nor does it have the proper origins in the impressions of sensation required to justify judgments about such phenomena as ‘matters of fact’ judgments. For Hume, this is a significant problem. This is what is known as Hume’s Problem: that we seem to have an idea of a necessary connection between cause and effect which does not match up with any of our original impressions of sensation or reflection, and is not a result of a relation between ideas which are generated the way all valid ideas based on perception must arise. This leads Hume to reexamine the idea of a causal relation to find a source of this aspect of that complex idea.

Hume returns to experiences that seem to contain instances of causal phenomena. These experiences all have in common the features of contiguity and succession, which had been explicated as necessary to the notion of a causal relation previously. In addition, Hume introduces the relation of constant conjunction between cause and effect. Constant conjunction is no more than having experienced events of the type associated with the cause and of the type associated with the effect, repeatedly in the past. From experiencing this constant conjunction of objects, the imagination projects the future existence of one (the effect) from the other (the
cause), and it is this psychological expectation that forms the basis for the idea that a causal relation between the two objects is a *necessitating one*, even though the connection between the events is, in fact, composed merely of four relations grounded in actual impressions of sensation: spatiotemporal contiguity, succession, resemblance, and constant conjunction. These four relations, all supported by impressions presented to consciousness, cannot justify the application of the idea of a *necessary connection* that is part of our complex idea of a causal relation, or, in other words, that the so-called cause *requires that* the so-called effect come about.

The constant conjunction between two objects, where one object is always observed to be followed by another, forms a link between the ideas of the objects in the mind. This link is such that thought of one object will lead one to think of the other. Their connection is generated by the imagination on the basis of a habitual association of the ideas of the events associated with the cause and the effect in each instance, producing a powerful inclination to anticipate the effect when the mere idea of the cause arises in the mind. This compulsion corresponds to the idea of the *easy transitions in thought* that constitute the association the mind draws between the ideas of cause and effect in the case of any constantly conjoined pair of phenomena and is not objective evidence of a necessary connection between the two phenomena as they are actually perceived to exist. Rather, it is the idea of those easy transitions of thought/associations between a particular cause and particular effect that constitutes the impression of reflection that stands, Hume discovers and asserts, as the true origin of the idea of a necessary connection between cause and effect in this, and all other cases of causal phenomena. Thus, the idea of a necessary connection is a psychological property drawn from the way the mind reacts to constantly conjoined, resembling, and spatiotemporally contiguous, yet successive events. Like Pavlov’s dog, these perceptible features of the phenomena generate a psychological compulsion to expect
the effect whenever the cause is perceived anew. But the source of this idea lies in the mind itself, and not in the content of perception, and hence, is illegitimately applied as a feature of the phenomenon as perceived.
III. THE PROCESS ONTOLOGY

ONTLOGICAL SHIFT

Wesley Salmon, in his 1984 book *Scientific Explanation and the Causal Structure of the World*, presents a theory of causation that involves an ontological shift from events to processes as the fundamental relata of the causal relation. Humean regularity theories subscribe to the event ontology, whereby C-type events are observed to be constantly conjoined with E-type events, and therefore, C-type events are said to E-type events. The discussion concerning the distinctions between the event ontology and the process ontology is forthcoming, however this section will be devoted to making explicit what precisely the process ontology is, and how Wesley Salmon’s theory of causation has evolved over time.

Processes are spatio-temporally continuous entities, which are not necessarily confined to the boundaries of a specific object, or aggregate of objects. Processes have greater temporal duration and spatial extent than events. In space-time diagrams, events are represented by points, whereas processes are represented by lines. Events are derivative of processes, however processes are not merely composed of discrete events that are temporally ordered. Processes are continuous entities, and describing them as collections of sequential events fails to represent that continuity fully. However, events are derivative of processes in that events can be “picked out” of processes, so to speak, in order to talk about a moment or small window of time. For instance, the moment a baseball hits a window is an event, but the baseball travelling from the bat, to the window, and through the window, is a process. The specific instance of the baseball’s collision with the window can be extracted from the process, but the process itself is the important entity to consider while analyzing the causal connection between the ball and the window.
Salmon takes some care to emphasize that a ‘process ontology’ is scientifically legitimate, and not inconsistent with the theories of special and general relativity. Before offering further explanation of this legitimacy, it is useful to demonstrate how the ‘event ontology’ has been supported on similar grounds. Hermann Minkowski\(^4\) demonstrated that the space-time interval between two events is an invariant quantity, which is independent of any frame of reference. Because this quantity exists between events, it is natural to conclude that space-time is a collection of events, which bear space-time relations to one another, governed at the extreme by this invariant quantity. Additionally, because there is a good reason to afford special status to invariant quantities in a ‘physical thing ontology’ (under which the natural sciences operate), the ‘event ontology’ seemed to be a natural way to represent the world.

However, points in space-time can be represented in an alternative way, which involves Minkowski light cones. From any point in space-time, a two-sheeted light cone can be constructed. The first sheet is generated by all of the possible light paths that converge on that point (past light cone), and the second sheet is constructed from all of the possible light paths that could be emitted from that point (future light cone). The pulses of light, which generate light paths, with which the past and future light cones are constructed, are processes. Giving the past and future light cones for each point in space-time determines the entirety of the structure of space-time. Thus, based on similar theoretical justification, a ‘process ontology’ can also account for the entirety of the structure of space-time, and is a perfectly legitimate way in which to represent that structure. On these grounds, Salmon concludes that neither ontology is privileged over the other. Further motivating the ontological shift from events to processes will take additional work, but first an account of processes and their interactions ought to be given.

\(^4\) Minkowski was a Lithuanian-German mathematician whose work on special relativity influenced Albert Einstein in his formulation of general relativity.
PROCESSES AND THEIR INTERACTIONS

There is a fundamental distinction that must be made between two types of processes: causal processes and pseudo-processes. This distinction is necessary because of special relativity, specifically the principle that states that no signal can be transmitted at a velocity greater than the speed of light. However, certain processes are capable of transpiring at arbitrarily high speeds, exceeding the speed of light. If those processes were somehow causing anything, where causation is considered a type of signal transmission, something would certainly be wrong. However, this observation simply means that these processes are necessarily pseudo-processes.

Pseudo-processes are distinct from causal processes, therefore, in that causal processes are capable of transmitting causal influence, while pseudo-processes are not.

Salmon introduces the criterion of mark transmission, which states that processes that are capable of transmitting a mark are causal processes, and pseudo-processes are incapable of transmitting a mark. This criterion offers a general way to distinguish between the two classes of processes, and a method by which to determine if a given process is causal or pseudo. The principle of mark transmission, designated MT, is as follows:

MT: Let P be a process that, in the absence of interactions with other processes, would remain uniform with respect to a characteristic Q, which it would manifest consistently over an interval that includes both of the space-time points A and B (A ≠ B). Then, a mark (consisting of a modification of Q into Q'), which has been introduced into process P by means of a single local interaction at point A, is transmitted to point B if P manifests the modification Q' at B and at all stages of the process between A and B without additional interaction.

This principle is prone to very serious objections, which will be addressed later; however, the general idea is illustrated well by one of Salmon’s examples. Consider a cylindrical building, in the middle of which is a spotlight. The spotlight shines a light at the wall, and is a causal process,
according to MT, which is demonstrable through the hypothetical introduction of a mark. While the light is shining at the wall, let us call some point between the wall and the light point A, and some other point between point A and the wall point B. While the light is shining (passing through points A and B) on the wall, a red lens is introduced at point A. Subsequently, the light is red from point A to the wall. Without any further interactions (that is, nothing else has changed), the characteristic color of the light (characteristic Q) has been modified to the color red (Q'). The light is red starting at point A, and through point B. Because the lens is a single local interaction that modifies a characteristic of the process, the process has been marked, and because of the beam of light’s capability to be marked\(^5\), the beam of light is said to be a causal process.

This example can be modified slightly to give an example of a pseudo-process. Suppose that the spotlight inside of the building is now rotating uniformly, casting the beam of light in a circle around the building. The same points A and B can be used, as the process still intersects both of these points. Now, consider what happens when the red lens is again introduced at point A. For a brief moment, the light becomes red, and then the rotation results in the beam no longer intersecting the lens, and the light is no longer red. It is clear that the process of the rotating spotlight cannot be marked by any interactions of this sort, as the mark cannot be manifested continuously after it has been introduced. Thus, the rotating spotlight process is a pseudo-process.

The rotating spotlight process example can be modified slightly to further convince one that it cannot be a causal process. Suppose for a moment that the cylindrical building’s radius

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\(^5\) A process’ capacity to be marked makes the formulation of MT explicitly counterfactual. This is a significant source of objection, and is puzzling, however it will not be addressed in this work.
was capable of expanding without limitations, and the spotlight was sufficiently bright to illuminate the wall no matter the radius of the building. Once the radius is sufficiently large, the velocity of the spot of light moving along the wall exceeds the speed of light! There is nothing wrong with this in the physical sense, but were the rotating spotlight a causal process, it would explicitly violate special relativity, which is prohibited for causal processes. However, because the rotating spotlight is, in fact, a pseudo-process, it is able to transpire at arbitrarily high speeds.

The principle of mark transmission allows us to draw some general conclusions about the differences between causal processes and pseudo-processes, and further explicate the properties of causal processes. Causal processes can both propagate and transmit causal influence, whereas pseudo-processes cannot. The propagation of causal influence is implicit in MT, and is essential to a process being thought of as “causal” at all. This propagation merely refers to the ability of a process to manifest characteristics continuously between space-time points along the path of the process. For instance, radio waves broadcasted from a tower propagate their causal influence in the frequency and wavelength of those waves. Both of these characteristics of the wave are manifested in the process *continuously*, and at all stages of the process between any given points. These characteristics, which are propagated in this way, are essential to the transmission of causal influence. Causal influence is transmitted when two or more causal processes interact via a causal fork (conjunctive, interactive, or perfect).

Causal interaction, according to Salmon, *produces* changes in processes. These changes are modifications made to the structure or the order of the process. These two concepts, ‘structure’ and ‘order’, have some relation to the aspect of the process to which the modification is applied, but the exact connection is unclear. The ‘structure’ of a causal process seems to be the kind of quality that determines *how* and to what *extent* the process is capable of interacting with
other causal processes. Additionally, the ‘structure’ of a causal process seems to be uniform or constant over the history of the process. The ‘order’ of a causal process seems to be the correlation between the structures of various processes, and is a kind of regularity between or among processes, which are produced via causal forks.

Causal interaction can be characterized by Salmon’s principle of causal interaction, designated CI, which is as follows:

CI: Let $P_1$ and $P_2$ be two processes that intersect one another at the space-time point $S$, which belongs to the histories of both. Let $Q$ be a characteristic that process $P_1$ would exhibit throughout an interval (which includes subintervals on both sides of $S$ in the history of $P_1$) if the intersection with $P_2$ did not occur; let $R$ be a characteristic that process $P_2$ would exhibit throughout an interval (which includes subintervals on both sides of $S$ in the history of $P_2$) if the intersection with $P_1$ did not occur. Then, the intersection of $P_1$ and $P_2$ at $S$ constitutes a causal interaction if:

1. $P_1$ exhibits the characteristics $Q$ before $S$, but it exhibits a modified characteristic $Q'$ throughout an interval immediately following $S$; and
2. $P_2$ exhibits the characteristic $R$ before $S$, but it exhibits a modified characteristic $R'$ throughout an interval immediately following $S$.

This principle can be separated into the three types of causal forks mentioned above: conjunctive, interactive, and perfect. These causal forks are rigorously defined through statistical relations between the conditions of processes involved before and after the interaction, however those relations are not significant to the conceptual discussion of the interactions, and are not included here. Briefly, a conjunctive fork is a causal interaction in which two processes arise from a single common causal process. An interactive fork occurs when two processes interact, and that interaction produces modifications in both processes. A perfect fork is a causal
interaction that captures the deterministic limit of both the conjunctive and interactive forks, and may be involved in the production or the modification of structure and order in causal processes.

**Processes versus Events in Probabilistic Cases**

Salmon’s account is able to explain all of the cases of causation that are already accounted for in Humean regularity theories, but has not yet shown the advantage of the process ontology in any of those cases, merely that the process ontology is consistent with normal accounts of causation. However, there is a class of cases, which provides a clear-cut difference between the two camps, and those are cases of so-called probabilistic causality.

Salmon presents the following thought experiment: suppose there is an atom in an excited state (referred to as the 4th energy level). This atom may decay to the ground state (0th energy level) in many different ways, all of which involve the intermediate occupation of the 1st energy level. Let \( P(m \rightarrow n) \) represent the probability that an atom in the \( m \)th energy level will spontaneously decay directly to the \( n \)th energy level. The following are two potential paths by which the atom can decay, and the associated probabilities of those decays:

- **Path A**: \( P(4 \rightarrow 3) = \frac{3}{4} \quad P(3 \rightarrow 1) = \frac{3}{4} \)
- **Path B**: \( P(4 \rightarrow 2) = \frac{1}{4} \quad P(2 \rightarrow 1) = \frac{1}{4} \)

From these probabilities, the chance that the atom will occupy the 1st energy level is \( \frac{10}{16} \). However, if the atom first decays to the 2nd energy level, its chance of decaying to the 1st energy level is \( \frac{1}{4} \). Thus, occupying the 2nd energy level is *negatively statistically relevant* to the atom occupying the 1st energy level. That is to say, the probability of the atom occupying the 1st energy level, given that it is occupying the 2nd energy level, is less than the probability of it

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P(1|A) + P(1|B) = \left( \frac{3}{4} \times \frac{3}{4} \right) + \left( \frac{1}{4} \times \frac{1}{4} \right) \rightarrow \frac{9}{16} + \frac{1}{16} = \frac{10}{16}
\]
occupying the 1st energy level unconditionally. Despite the negative statistical relevance, it cannot be denied that the occupation of the 2nd energy level is a direct antecedent to the atom occupying the 1st energy level in Path B.

The causal chain that contains Path B is a genuine series of events by which the atom decays, however, Humean statistical regularity theories cannot account for the negative statistical relevance relation between the series of events that are integral to that path. This is due to the formulation of these theories, which hold that “a cause which contributes probabilistically to bringing about a certain effect must at least raise the probability of that effect” (Salmon, 1984, pp.68). This criterion is known as positive statistical relevance, and is fundamental to statistical regularity accounts because if a so-called cause does not raise the probability of its effect, then it cannot be said to bring it about. The fact that the atom’s occupation of the 2nd energy level is negatively statistically relevant to (i.e. lowers the likelihood of) the atom’s occupation of the 1st energy level, while at the same time being two events in a genuine causal chain, is a strong objection to theories of this kind.

Salmon’s process ontology is capable of dealing with such cases. Analyzing the case under a process ontology, the atom constitutes a causal process. Each path is a possible future state of the process, and each particular state of the atom has what Salmon calls a propensity. A propensity is “less-than-deterministic tendency [of a process] to produce a certain interaction” (Dowe, 1992, pp.199). In this case, the interaction produced is the decay of the atom to any particular energy level, and the propensity corresponds to the probability of that decay. Without appealing to these propensities for a causal explanation, the process ontology states simply that each path is possible given the Minkowski light cones of the atom, with certain interactions
being favored based on these propensities. No mention of statistical relevance, positive or negative, appears in this explanation.

**OBJECTIONS TO THE PRINCIPLE OF MARK TRANSMISSION**

The above summary of Wesley Salmon’s account is an accurate reflection of the account he gives in 1984, which is prone to an objection that renders the account incapable of distinguishing causal processes from pseudo-processes. Without the ability to account for this fundamental distinction, which is required in the initial formulation of the process ontology itself, Salmon’s initial account falls apart.

Let us first examine Salmon’s own example: the pulse of light travelling from a spotlight to a wall, with a single local intervention at a red lens partway between the spotlight and the wall. The beam of light, prior to interacting with the red lens, has certain characteristics that determine the way that it causally interacts with the world. For instance, it contains a broad spectrum of wavelengths, which causally interact both with the air around the beam (heating it) and with us, the observers, in a way that allows us to visually perceive the beam. These, and other interactions of the kind, seem to be the fundamental characteristics of that light beam. The types of characteristics that are fundamental to a causal process may be a controversial issue, and the root of that issue is a question of identity. Without attempting to solve such issues here, I will say that the characteristics which are the best candidates for being fundamental are those which directly determine the causal interactions that process P has with other causal processes (what Salmon might call the structure of the process). This is very broad, as almost all characteristics of a causal process determine precisely how that process is able to causally interact with other processes. Returning to the beam of light, let us ask: which characteristics are being altered when
the beam passes through the red lens? The ways in which it interacts with the air and the ways in which it is observed are changed. The only things about it that seem to be the same are its light-ness and its beam-ness. Its light-ness merely refers to the stuff that it’s made of, but not any particular type of that stuff, and its beam-ness merely refers to the way that stuff is arranged. These two characteristics of the light are not enough to say that the beam of light (process P) is the same process before and after passing through the red lens.

This does not yet prove that the principle of mark transmission is not adequate to distinguish between causal and pseudo-processes. Salmon often talks about a causal process’ capacity for transmitting marks, not that it is actually transmitting a mark. As stipulated in MT, a mark is a characteristic Q’ that is a modification of some characteristic Q. Presumably, to determine if a mark is transmitted, Q’ must be measurably distinct from Q. However, if Q’ is a characteristic of a process that is not P, Salmon’s principle cannot account for any marks at all because the two processes are non-identical. Then, a causal process is not even capable of transmitting a mark, because the marking event transforms the process P into a related, but still distinct, process P’. Because process P can no longer exist after a marking event, it cannot transmit a mark from point A to point B.

The principle of mark transmission explicitly states that it is process P which is marked and transmits that mark without further intervention. However, I believe I have reasonably demonstrated that the characteristic Q is fundamental to process P, because that characteristic determines the causal interactions that process P is capable of having with other causal processes. The entirety of the mark transmission principle depends on process P persisting through the marking event at point A, and manifesting the mark Q’ at all intervening steps of the process to point B. Because process P does not, in fact, persist through the modification, the
principle of mark transmission does not provide an adequate method for distinguishing causal processes from pseudo-processes.

This is not the only objection to the principle of mark transmission\(^7\), however I believe that this objection alone is sufficient to reject the principle. Because Salmon’s theory as a whole relies heavily on this principle to establish a method by which to distinguish causal from pseudo-processes, it is clear that the process theory of causation requires a significant revision to be fruitful in accounting for causation.

**Dowe’s Conserved Quantity Theory**

Phil Dowe has proposed a revision to Salmon’s original theory (Dowe, 1992), which introduces the concept of a *conserved quantity*. Dowe provides two definitions to base this modified process theory on:

*Definition 1:* A causal interaction is an intersection of world lines which involves exchange of a conserved quantity.

*Definition 2:* A causal process is a world line of an object which manifests a conserved quantity.

A world line is a collection of points on a space-time diagram which describe the history of an object. A conserved quantity is any quantity which is universally conserved according to current scientific theories (Dowe, 1992, pp.210). Some examples of conserved quantities are mass/energy, linear momentum, electric charge, and angular momentum. For a conserved quantity to be exchanged simply means that at least one “outgoing” and one “incoming” process manifest a change in the value of a conserved quantity. “Outgoing” and “incoming” are arbitrary designations based on the Minkowski light cones, and are essentially interchangeable.

\(^7\) For more, see: Dowe, 1992.
An example interaction may help to illuminate these ideas further. Suppose there are two billiard balls on a pool table. Each ball in its current state is a causal process, let us call them C and E. If ball C, moving at some velocity, strikes ball E, which is stationary, ball E will begin to move at some velocity and ball C will continue to move at a decreased velocity. Because our current scientific theories tell us that linear momentum is a conserved quantity, it is clear that this is an example of causal interaction. Ball C, possessed of some amount of linear momentum, intersects the world line of ball E, transferring linear momentum to it, satisfying Definition 1. These are the types of interactions, on a macroscopic and microscopic level, that constitute causal interactions.

Salmon has largely accepted Dowe’s revisions of his account, with several proposed changes of his own. For the sake of presenting the viewpoints of Salmon as they evolved over more than a decade, I shall include Salmon’s revisions (up to 1997) without the argumentation for each. Beginning with Dowe’s definitions, Salmon modifies Definition 2 and adds a third definition (Salmon, 1997).

**Definition 1:** A causal interaction is an intersection of world lines which involves exchange of a conserved quantity.

**Definition 2:** A causal process is the world-line of an object that transmits a non-zero amount of a conserved quantity at each moment of its history (each space-time point of its trajectory).

**Definition 3:** A process transmits a conserved quantity between A and B (A ≠ B) if and only if 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.
Salmon believes that the above three definitions\textsuperscript{8} provide a full account of causal processes, causal interaction, and causal transmission. Definition 3 is a type of restatement of Salmon’s criterion of mark transmission (MT), included in his 1984 account of causation. This reformulation of MT is not prone to the objection given above, as it makes no appeal to the characteristics of the process. Conserved quantities appear to be exactly the kinds of “fundamental characteristics” I posited in that objection, and Salmon seems to acknowledge this to some extent. The theory adequately distinguishes between causal and pseudo-processes, in that pseudo-processes do not transmit conserved quantities (by Definitions 2 and 3).

It seems that, without giving up the simplicity and empirical nature of Dowe’s theory, Salmon has given an account of causation which explains causation in an intuitive way. Section IV will examine whether or not Salmon’s version of the conserved quantity theory of causation avoids Hume’s problem, while at the same time providing a metaphysical account of the necessary connection between cause and effect.

\textsuperscript{8} Including a corollary given explicitly to deal with one type of counter-example that is not immediately relevant to the topic specifically at hand.
IV. PROCESSES AND HUME

Wesley Salmon, in his original 1984 work, claims that he provides “a complete answer to Hume’s penetrating question about the nature of causal connections” without “appealing to any of the ‘secret powers’ which Hume’s account of causation soundly proscribed” (Salmon 1984, pp.157, 155). In this section, I will examine whether or not Salmon has done what he claims, by analyzing the conserved quantity theory of causation in a Humean framework.

PROCESSES IN THE HUMEAN FRAMEWORK

A process is a complex idea, which must have its origins in impressions of sensation. Processes are spatio-temporally continuous objects, or aggregates of objects. Consider for a moment a baseball travelling towards a window. Our impressions of the baseball are clear enough, and the idea generated of the baseball through those impressions is a standard complex idea of an object. But, what did you imagine when I prompted you to consider a baseball flying through the air? What is merely a baseball, perfectly still, in the absence of any context or temporal duration? Personally, the image conjured in my mind’s eye was more complex than that; it was of a baseball moving from left to right across my field of vision, obviously in motion, rotating around its internal axis and arcing in a characteristic parabola. Perhaps your imagination of the baseball was slightly different, but the idea is still the same: the baseball is imagined as a process, and not merely an object.

In order for one’s impressions to generate the complex idea of a process, the impressions must contain all of the essential features of the process and the ideas of each must be associated with each other (which, given the spatio-temporal contiguity of the impressions from which they
arise, will be the case): the object itself, the spatial continuity of the process, and the temporal continuity of the process. The object itself, as shown in Section II, is a standard complex idea of a sensory bundle, generated through impressions of the object and consequent associations of the resulting, bundled ideas in memory, disregarding its motion or activity, or its temporal duration.

When considering space and time, Hume claims that both are imperceptible, unless they are regarded in terms of an object. This fits quite nicely with processes, as processes require both an object and the spatio-temporal continuity of that object. The impressions that correspond to the spatial continuity of an object are none other than impressions of its extension and its motion. Extension, according to Hume, is a compound idea of sight and tangibility, specifically the color and solidity of each indivisible part of an object. When each indivisible part of an object is aggregated into the whole of the object, we perceive the extension of that object. This extension is continuous, insofar as the aggregation of the object is continuous. Therefore, the object alone has certain aspects of spatial continuity. In addition, when the object is in motion, that motion is spatially continuous. During continuous observation of an object in motion, our impressions reveal that the object smoothly changes its relations to the objects around it, admitting of no “jumpiness”, or non-continuity. Impressions of processes are spatially continuous, due to the associations made between distinct impressions of the object along its trajectory.

Time, like space, must be conceived in terms of an object, in that “the indivisible moments of time must be filled with some real object or existence, whose succession forms the duration, and makes it be conceivable by the mind” (Hume, 1739, pp. 21). This is to say that the object, as it persists, forms a duration associated with the impressions from which our idea of the object is formed. Perceptions of objects, then, have temporal duration as long as the impressions on which they are based are so strongly associated that we develop the idea of their persistence.
Temporal duration depends merely on the strong associations among the impressions of the object. Under normal conditions of perceptions, therefore, objects have temporal duration and temporal continuity.

Thus, processes as complex ideas have as their direct source a complex array of strongly-associated impressions. Treating each object as a process, and no longer as an object, is quite natural and intuitive in the Humean framework, being based upon strongly associated copies of incoming impressions accounted for by the selfsame theory of ideas that underwrites his account of our complex ideas of objects. Separating the object from the process can be done, of course, but I believe that this act of separation is an active process of the intellect analyzing the origins of the complex ideas in question, and not the result of any difference in the original impressions of sensation on which each is based. In fact, the idea of an object devoid of spatio-temporal continuity requires that one actively dissociate that idea from its spatio-temporal contiguity. The impressions described above (extension, continuity, and duration) are integral to one’s impressions of any object, implying that processes are as equally fundamental as objects when considering the origins of one’s ideas.

**Conserved Quantities**

Causal processes have another necessary feature, the manifestation of a non-zero amount of a conserved quantity. This feature contains two distinct ideas: a conserved quantity and the manifestation of a non-zero amount of that quantity. Manifestation of an amount of a quantity seems to be the idea that is most easily traced back to impressions. Linear momentum, which is one example of a conserved quantity, is a quantity determined by an object’s mass and velocity. An object’s mass, which is somewhat related to its extension, can be perceived in tactile
impressions of the object, in many cases. Going back to the baseball, hefting it in one’s hand
would give one an impression of the baseball’s weight, and therefore mass. Next, an object’s
velocity is perceived in impressions of the rate of change of its relations to objects around it.
These impressions do not reveal the precise value of the object’s mass or velocity, but they do
reveal that the object manifests those quantities. Thus, if an object manifests mass and velocity, it
necessarily manifests a non-zero amount of linear momentum. Similar analyses could be done
for the other conserved quantities employed by Salmon (angular momentum, mass/energy, and
charge). However, this does not provide sufficient insight into the nature of a conserved quantity
itself.

A conserved quantity is any quantity universally conserved according to current scientific
theories. For a quantity to be universally conserved, that means that the amount of that conserved
quantity (in a closed system) is constant. This means that if one process loses some amount of a
conserved quantity due to an interaction, one or more distinct processes must gain that same
amount. In a Humean framework, we must search for original impressions which correspond to
the idea of a conserved quantity. As shown above, impressions of the quantity itself are not
difficult to trace, at least for momentum and the other macroscopic quantities proposed.
However, these quantities go beyond their mere manifestation, they also are conserved across
interactions.

In order to determine that a quantity is conserved, impressions just prior to the interaction
must be quantitatively compared to impressions just after the interaction. Specifically, the
impressions of an amount of a quantity prior to the interaction must be quantitatively identical to
the impressions of the amount of that same quantity after the interaction (in a closed system).
Due to empirical limitations of our senses, it is highly improbable that one could compare precise
values of any quantity between any two impressions. However, let us assume that there is a reliable and accurate measuring device available to us, allowing such a comparison to be possible. Consider two billiard balls, call them ball C and ball E, on a pool table. Ball E begins stationary, and therefore has a linear momentum of zero. Ball C, on the other hand, begins in motion towards ball E, manifesting some non-zero amount of linear momentum. Our measuring device records this momentum just prior to the collision between the two balls. After the collision, both ball E and ball C are in motion, though ball C is moving slightly slower than previously. Our measuring device takes another reading, and now the sums of the linear momentums’ of the balls can be compared before and after. If linear momentum is indeed conserved, the following equation must be true:

\[ P_i(C) + P_i(E) = P_f(C) + P_f(E) \]

With the help of our measuring device, this equation can indeed be shown to be true, in this scenario. But, this alone does not justify the claim that linear momentum is universally conserved.

According to Salmon and Dowe, conserved quantities are determined by current scientific theories. Potentially, the reliance on scientific theories could lead to circularity in the formulation of the conserved quantity theory, and the theory would fail to solve Hume’s problem of causation by default. The essential question to ask is: do scientific theories presuppose causation as an objective feature of the world? If indeed they do, then Salmon and Dowe’s conserved quantity theory is purely a description of what scientists assume when they formulate scientific theories. The question posed is a topic of large debate in the philosophy of science.

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9 This example is meant to be under idealistic conditions, where friction, air resistance, etc. are negligible and the table represents a closed system.
10 \( P_i(C) \) refers to the initial (i) linear momentum (P) of ball C (C). Similarly, \( P_f(E) \) refers to the final (f) linear momentum (P) of ball E (E).
today, and that debate is beyond the scope of this paper. As we will see, although this point is important, it is not necessary to the current analysis of the conserved quantity theory. There are sufficiently powerful objections to be found elsewhere.

THE POWER OF EXCHANGE

In Salmon’s conserved quantity theory, he provides a definition which characterizes causal interactions as the following:

Definition 1: A causal interaction is an intersection of world lines which involves exchange of a conserved quantity.

This definition states that causal processes intersect and exchange a conserved quantity. The key idea here is that of “exchange”. We turn once more to potential original impressions of this exchange. In the intersection of processes, it is clear that the processes possess some conserved quantity both before and after the exchange occurs. However, merely observing these relative amounts of the conserved quantity before and after the intersection of two processes is not enough to constitute the idea of an exchange, in the way Definition 1 describes. A causal interaction is not defined as an observed difference in amounts of conserved quantities prior to and following said interaction; rather it essentially requires an exchange to take place. In searching for original impressions of such an exchange, I am reminded of Hume’s critique of the term “production”: (Hume, 1739, pp.43)

“Should any one [...] pretend to define a cause, by saying it is something productive of another, it is evident he would say nothing. For what does he mean by production? Can he give any definition of it, that will not be the same with that of causation? If he can; I desire it may be produced. If he cannot; he here runs in a circle, and gives a synonymous term instead of a definition.”
I pose the same question to Salmon and Dowe: what is meant by exchange? Dowe stipulates\(^{11}\) that “an exchange means at least one incoming and at least one outgoing process manifest a change in the value of the conserved quantity” (Dowe, 1992, pp.210). This is insufficient to establish that causation is an objective feature of the world, because it essentially reinforces Hume’s analysis of causation.

If we substitute Dowe’s definition of exchange into Salmon’s Definition 1, we get the following:

*Definition 1*: A causal interaction is an intersection of world lines which involves at least one incoming and at least one outgoing process [manifesting] a change in the value of [a] conserved quantity.

This notion of exchange is easily traceable to original impressions, as stated previously. However, this notion of exchange does nothing to establish causation as an objective feature of the world. There is no appeal to any sort of necessary connection, causal production, literal quantity transference, etc., which makes the conserved quantity theory essentially a process-based regularity theory. The incoming and outgoing processes, which manifest changes in the value of some conserved quantity, are not connected in the way required to establish that their connection is causal, in the sense of causal that Salmon would like to use. They display contiguity and succession, but not necessary connection.

Salmon (along with Dowe) reinforces Hume’s analysis of the causal relation, but fails to realize it. Salmon claims that causal processes “constitute precisely the objective physical causal connections which Hume sought in vain” (Salmon, 1994, pp. 297). This

\(^{11}\) Salmon does not explicitly examine Dowe’s notion of “exchange”, but recounts Dowe’s definition without comment, which I am taking to mean that Salmon agrees with the definition as given.
is impossible. Humean strictures are essentially empirical requirements of accounting for the source of one’s ideas. Hume’s problem of causation is implicit in the empirical framework, and unavoidable without rejecting (at least some of) basic empiricist principles. Salmon’s account is highly empirical, while attempting to prove a point which is contradictory with empiricism on a fundamental level. Causal processes, the complex idea of which does have its origin in impressions of sensation, are not themselves sufficient to posit that the causal relation exists as a necessary relation between processes; something more is needed. This ‘something more’ could have been the notion of “exchange”. However, “exchange” in the conserved quantity account is nothing more than impressions of sensation that indicate a change between the prior and subsequent amounts of a particular quantity across an interaction. This is all that the notion of “exchange” can be in an empiricist framework. Anything more would go beyond one’s immediate impressions, violating the basic premise of Hume’s empiricism – all ideas must have their proper origins in impressions of sensation, reflection, or emotion.

For instance, “exchange” could have meant that a process literally transfers some amount of a conserved quantity to another, necessitating that the recipient process manifests some changes in that quantity. This account of exchange would establish that the causal relation is a force by which the cause actually brings about the effect. However, this account is also unjustifiable by appeal to original impressions. In order to assert this definition of “exchange”, one would have to assume that there is some other source of one’s ideas, separate from impressions, which also produces intelligible and meaningful ideas. What exactly that source may be is beyond the scope of this paper.
Salmon describes the three definitions given as the foundation of the conserved quantity as “impeccably empirical” (Salmon, 1997, pp.469). Because of this, I believe that Salmon has not provided the answer to Hume’s problem of causation that he claims he has. Instead, Salmon has given an account of causation which arrives naturally at the same conclusion as Hume, without stating it explicitly. This conclusion is that all so-called causal interactions are observed instances of regularity.

Salmon’s account still retains the advantages that processes have over events in the problematic cases, e.g. probabilistic cases of negative statistical relevance. Because there is no relevance condition anywhere in the conserved quantity theory, causal interactions can be parsed out as merely observed differences in amounts of a conserved quantity across an interaction. This is perfectly acceptable to account for cases of negative statistical relevance, as outlined in Section III. In this way, the conserved quantity theory answers objections posed to event-based regularity theories, but does not solve the fundamental issue Hume’s problem of causation is meant to elucidate: that of a necessitating relation between cause and effect. The conserved quantity theory, as formulated, is a process-based regularity theory, which focuses on aligning itself with a contemporary scientific understanding of which interactions constitute relations that are subject to conservation laws.
V. Conclusion

The narrow notion of “exchange” in describing causal interactions renders Salmon’s conserved quantity theory a process-based regularity theory. There is no doubt that Salmon (and Dowe) would object to this charge, however there are no concepts employed by the conserved quantity theory which may suggest a more metaphysically robust conclusion. A careful reading of the terms and definitions used reveal that no account of an objective, necessitating causal relation is being given. This is not to say that the conserved quantity theory fails to have explanatory power regarding causal interactions, merely that those causal interactions must be clearly understood as observed changes across an interaction, without making further metaphysical claims which have no justification.

Salmon claims that “[process theories of causality provide] an answer to Hume’s famous question about the nature of causal connections” (Salmon, 1997, pp.462). This kind of language implies that Salmon believes the conserved quantity theory supports metaphysical claims about the true nature of a necessitating causal relation. In fact, what the conserved quantity theory does do is explain causal interactions in terms of regularly observed changes in manifestations of quantities across an interaction. Causal interactions, understood in this way, have powerful explanatory power in scientific exploration, including cases which are problematic for Humean, event-based regularity theories (such as cases of probabilistic causation that exhibit negative statistical relevance).

I believe that Salmon’s fundamental mistake is the lack of explicit analysis concerning the actual metaphysical implications of the conserved quantity theory.
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