SINGULAR CAUSAL STATEMENTS AND STRICT DETERMINISTIC LAWS[1]

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Singular causal statements, which I take to express relations between events, have often been thought to have some important connection with strict deterministic laws, perhaps even to be analysable in terms of them. In this paper I argue that none of the kinds of strict deterministic law that may exist relate events to a non-arbitrarily selected part of what absolutely precede them, and hence that none are of avail for distinguishing what causes an event from what absolutely precedes it. I shall say that a *absolutely precedes* b if and only if a is not so distant from b that signals from a would need to travel faster than the speed of light in order to reach b.[2]

In section I I argue that we cannot tell whether there are any strict deterministic laws couched in terms of ordinary language just by examining attempts at sharpening up familiar generalizations. Then in section II I argue that if and only if fundamental physics is deterministic there will exist a certain kind of maximally detailed strict deterministic law. And in section III I argue that by modifying these maximally detailed laws we can produce various different kinds of strict deterministic law, but that none of these affords a way of distinguishing causation from absolute precedence. Finally in section IV I examine Davidson's view of the relation between singular causal statements and strict deterministic laws, thereby elaborating on the conclusion of the previous section, and I point out that this conclusion raises problems for his argument for anomalous monism.

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I

What are strict deterministic laws? I take a law to be a true lawlike generalization, i.e. a true sentence, not a fact (though I am assuming it can exist without any inscriptions), and a strict law to be one that is exceptionless. In this paper I shall be concerned, except where otherwise stated, with laws of succession—those laws relating phenomena at different times or in different time intervals. (I use 'phenomena' as a broad term covering events, states, and conditions. I take events to be individuated by way of their spatio-temporal location, though the arguments can be adapted to apply to finer-grained events.) Such laws may be predictive (I shall call these (P)-laws) or retrodictive (I shall call these (R)-laws). A law of succession is deterministic—as opposed to indeterministic or probabilistic—if and only if it states that a phenomenon of some type invariably occurs at a point in time, or in a time interval, rather than just has a certain probability of doing so, given the occurrence of a phenomenon of a certain type at another point in time, or in another time interval.

Are there any strict deterministic laws? Let us begin by examining whether we can produce any by sharpening up familiar generalizations couched in the terms of ordinary language. Take, for example, the generalisation that matches ignite after being struck. This is not a strict deterministic law as it stands, but we can get closer to finding one by adding more conditions, e.g. that the match has a certain chemical composition, is dry, is struck with a certain force, in an oxygenated atmosphere, etc. It might be hoped that we would eventually come upon an exceptionless law once we'd specified a suitable range of humidity, wind strength, atmospheric pressure, etc., obtaining within some region in which cause and effect take place. But for this to be at all plausible, the conditions would need specifying for the entire time interval between cause and effect, for otherwise some intervention could occur, e.g. someone could pour a bucket of water over the match just after it is struck.

Suppose we try to rule out interventions by specifying conditions applying at the time the match is struck, e.g. that there is no one standing beside the match with a bucket of water, no tornado or meteor is about to strike, no black hole is nearby. The trouble with this approach is that presented with a putative strict deterministic law of this form, it always seems easy to think of extra counterexamples arising from further ways of intervening. We cannot avail ourselves of the condition that no intervention-producing circumstance is present (for this would be patently circular), nor of any clause to the effect that conditions are normal (for this would render the law non-objective).

Suppose instead we try to rule out interventions by specifying conditions applying for the entire time interval in which the effect can occur. As the vagueness of ordinary language predicates rules out the possibility of predicting the precise time at which the effect occurs, the event constituting the effect (e.g. the igniting of a match) must occur within some temporally extended interval. And this means that the phenomenon constituting the cause (the event together with the conditions) must occur in some time interval overlapping that in which the effect occurs, since the causal conditions must be specified right up until the last possible moment the effect can occur in order to rule out all possibility of intervention. I shall not examine whether the presence or absence of laws of this kind could be used to mark a distinction between causation and absolute precedence; nor shall I explore any further in this way whether such laws exist, since there seems to be no way to tell from examining individual generalizations whether they could ever be made exceptionless.[3]

II

Instead let us adopt a different strategy in asking whether strict deterministic laws are possible. To this end I shall construct an extravagantly detailed form that such a law might take and then look at ways of relaxing some of the detail and the restrictions imposed in this construction. Laws of this form are just philosophical constructions of no scientific interest, and I will shortly discuss how they are related to fundamental scientific laws. To simplify matters I shall begin by considering just predictive laws relating instantaneous, non-temporally-extended, events and states.

In order to rule out the possibility of intervention the law must apply to different states of a closed system or it must relate regions of space large enough to guarantee that nothing outside could interfere. Concerning the first option, there is no system other than the whole universe that is closed to all physical interference, and physical interference must be eliminated if the law is to be strict. A law relating states of the universe may be strict and deterministic but it would not be directly serviceable for analysing singular causal statements, which invariably relate states not of the whole universe but of much smaller finite regions. We may take a first step towards deriving suitable laws by picking as consequent a state of some small region that might be occupied by some event described in a singular causal statement. This brings us to the second option.

Concerning this second option, suppose we are seeking a strict deterministic law that will yield, from some feature of a region of space at time t, some further feature of a spherical region of space of radius r and centre $(p,t+\varepsilon)$, where p is a triple locating the point within some spatial frame of reference, and t+ε is a number locating the time. ('t', 'p', and 'r' are variables. Although I am incorporating the time coordinate into the centre of the region, this region is to be understood as spatially, but not temporally, extended.) Then the region of space, some feature of which needs to be supplied at time t, is that with centre (p,t) and radius r+cε, where c is the speed of light. It needn't be larger since, assuming that nothing can travel faster than light, there is no way that anything happening outside the sphere of radius r+cε at t can affect things inside the sphere of radius r at t+ε. And it cannot be smaller since, as I shall argue, choice of some smaller region at t can never guarantee that no significant intervention will occur.

Thus one form that such a predictive law could take is:

(P1) $(p)(t)(K^{\#}(p,t) \rightarrow L(p,t+\varepsilon))$

where '$K^{\#}$' and 'L' assign properties to these regions.[4] (I use '#' for predicates expressing properties of the very large region.) In plain language, (P1) says that when conditions of a certain type hold in a large region, then conditions of another type hold shortly thereafter in a small region. For example, '$K^{\#}(p,t)$' could say that a short circuit is occurring within a spherical region of radius r+cε and centre (p,t), and 'L(p,t+ε)' could say that a fire is occurring within a spherical region of radius r and centre (p,t+ε). (This choice of examples is designed merely to demonstrate the form of '$K^{\#}$' and 'L', not to make (P1) true.)

And if we want the law to say that events of a certain type occurring in a large region are invariably followed shortly thereafter by events of another type occurring in a small region, it can be written in the following form:

(P2) $(p)(t)(x)((F^{\#}x \;\&\; C(x)=(p,t)) \rightarrow (\exists y)(Gy \;\&\; C(y)=(p,t+\varepsilon)))$

where 'x' and 'y' range over events, 'C' is a function assigning a quadruple to an event to mark its centre, and '$F^{\#}$' and 'G' express properties of events occupying these regions.[5] For example, $F^{\#}$ could be the property of being a short circuit within a spherical region of radius r+cε, and G could be the property of being a fire within a spherical region of radius r. (Again these examples of predicates are not chosen to make (P2) true.)

What kind of predicate do we require to produce strict deterministic laws of the form (P2)? The most detailed strict deterministic laws would come from taking '$F^{\#}$' and 'G' to be what I shall call *complete physicalistic* predicates—those assigning values of all the fundamental physical parameters throughout these regions. These parameters, jointly sufficient and severally non-redundant for describing the complete range of fundamental physical phenomena, would be specified by means of a list in

accordance with the particular fundamental physical theory. A fundamental physical theory I shall characterize, roughly, as one that accounts for the fundamental phenomena upon which all other physical phenomena surpervene. Such maximally detailed laws may deal with discrete particles, or with continuous fields. They are philosophical constructions of no scientific interest and differ in two main ways from what might be called fundamental laws—laws of the fundamental theory, such as Maxwell's field equations or Newton's law of gravitation. Maximally detailed laws hold in virtue of all the forces of nature while the fundamental laws generally concern just a single force. And maximally detailed laws have a specific type of physical state as antecedent while fundamental laws do not. The fundamental laws together with a maximally detailed state-type description determine a maximally detailed law. Thus there can exist maximally detailed strict deterministic laws if and only if the fundamental laws are strict and deterministic. Though the fundamental laws may themselves be strict and deterministic, they are of the wrong form for distinguishing what causes an event from what absolutely precedes it since they do not have state-type descriptions as their antecedents.

Maximally detailed laws may take the form (P1) in which '$K^{\#}(p,t)$' is 'distribution of parameters $k^{\#}$ occurs in a spherical region of centre (p,t) and radius r+cε', and 'L(p,t+ε)' is 'distribution l occurs in a spherical region of centre (p,t+ε) and radius r'.[6] And they may take the form (P2), in which '$F^{\#}$' is 'is the occurrence of distribution $k^{\#}$ in a spherical region of radius r+cε' and 'G' is 'is the occurrence of distribution l in a region of radius r'. However, these forms are unsuitable for analyses of singular causal statements since the antecedent involves reference to events occupying much larger regions than those normally referred to in singular causal statements.

To remedy this we can construct laws taking a hybrid of the above forms which say that when conditions of a certain type hold in a large region (let's call these conditions background conditions[7] and call this region the background region) and an event of a certain type occurs within a small part of this region (let's call this region the foreground), then an event of some type occurs shortly thereafter. Thus if we now select from within this large region (sphere of radius r+cε) a smaller region (sphere of radius r*) as foreground representing the type of event we wish to appear in the antecedent of the law, and call the remaining part of the large region the background, then we can give as a new form for the law:

(P3) $(p)(t)(x)((K^{\#}(p,t) \;\&\; Fx \;\&\; C(x)=(p,t)) \rightarrow (\exists y)(Gy \;\&\; C(y)=(p,t+\varepsilon)))$

where 'F' expresses some property of an event occupying the foreground, '$K^{\#}$' assigns some property to the background, and the remaining symbols are as in (P1) and (P2). I have simplified by choosing to make the foreground a spherical region with the same spatial centre as the G-type event. But it should be obvious that any division of the large region into foreground and background is possible. The shape, size and location within this large region of foreground and background are completely arbitrary.

We can see now that maximally detailed laws may take the form (P3) in which 'F' is the predicate 'is the occurrence of distribution k of parameters in a spherical region of radius r*', '$K^{\#}$(p,t)' is 'distribution $k^{\#}$ occurs in a large spherical region of radius r+cε (omitting the small spherical region of radius r*) and centre (p,t)', and 'G' is 'is the occurrence of distribution l in a region of radius r'. Although we picked the F-type and G-type events to be spherical, it is easy to see how the result could be generalized to cover predictive maximally detailed strict deterministic laws relating types of events of arbitrary shape and size, so long as the F-type event absolutely precedes the G-type event. This allows us to see, intuitively, that laws of this kind relate events to arbitrarily selected parts of what absolutely precede them and so won't help us distinguish absolutely preceding events from causes.

III

Let us now examine ways in which less detailed strict deterministic laws may exist, by modifying these maximally detailed ones, to see whether they can be used to make a distinction between causation and absolute precedence. We can derive a multiplicity of less detailed laws by using physicalistic predicates in the consequent that are incomplete (in the sense that not all the parameters are specified at every point in the region) provided that the predicate used in the antecedent is complete. But since the antecedents of such laws are no different from those of the maximally detailed laws, these laws cannot provide a basis for distinguishing causation from absolute precedence.

A number of ways of producing laws by further relaxing some of the detail can be regarded as highly implausible given current views of fundamental physics. No further laws may be produced by leaving a parameter unspecified at any point in the antecedent region, for the value of the unspecified parameter would be sure to affect the values of the specified parameters in the consequent region, if only to the most microscopic degree.[8] And there can be no strict deterministic laws relating just some parameters throughout the regions. For the distribution of each parameter in the small region given in the consequent will be affected, directly or indirectly, by the distribution of *all* the parameters in the large region given in the antecedent, so there can be no strict deterministic law

that doesn't include all these parameters in its antecedent. If we require only that the consequent give some function of the parameter within the region, such as its sum or mean, rather than its exact distribution, then we will still need the complete distribution of all the parameters in the antecedent region, for the value of any unspecified parameter in the antecedent region would be sure to affect the values of the parameter in question at the boundary of the consequent region and hence the sum or mean of that parameter within the region.

We may derive further less detailed strict deterministic laws by way of what might be termed *supervenience laws*. These are not laws of succession but laws stating that if something satisfies a complete physicalistic predicate, 'S', it also satisfies an ordinary language predicate, 'O'.[9] We can derive further strict deterministic laws by replacing 'S' by 'S and O', and if 'S' occurs in the consequent of the conditional we can replace 'S' by 'O' alone. But again we cannot use these laws to distinguish causation from absolute precedence since the supervenience law can apply to *any* part of the large region given in the antecedent.

Now do all strict deterministic laws containing ordinary language predicates follow in this way from physicalistic laws, and contain complete physicalistic predicates in the antecedent of the conditional? One might think that if the predicate in the consequent has been replaced by an ordinary language predicate, say 'is a singing', then there would exist further laws in which the predicate in the antecedent is less than complete. But a parameter could not be left wholly unspecified anywhere in the antecedent region, for an extreme filling in of that parameter could always be imagined which would so disrupt the physical configuration in the consequent region that there would no longer be a singing there.[10] Nor is it plausible that a small part of the antecedent region could be specified exactly while the whole of the remainder of the region is specified in terms of a range for each parameter. For each range would have to be extremely narrow to create a good chance of keeping the law exceptionless, yet it would have to be quite broad to accommodate the usual variations that occur in the actual world. And if I am right that the predicate in the antecedent must be complete if it is physicalistic, then there will be no strict deterministic laws in which any part of the antecedent region is given solely by means of an ordinary language predicate.

Further strict deterministic laws may be derived from those already mentioned by taking disjunctions of those predicates 'F & $K^{\#}$' that may serve as antecedent for a given consequent. But this will only lead to a basis for distinguishing causation from absolute precedence if some divisions into foreground and background may be treated differently from others, which can only be done if either foreground or background can be expressed as a single disjunction. In general this will not be possible since the disjunction of all possible predicates 'F & $K^{\#}$' cannot be replaced by the disjunction of the 'F' predicates conjoined with the disjunction of the 'K#' predicates.

And further strict deterministic laws may be derived which relate events of non-zero duration. For if a maximally detailed strict deterministic law of the form (P2) exists relating a state of a large region at time t to a state of a small region at a later time t′, it seems clear that similar laws would exist relating the state of the large region at time t to a state of the small region at any intermediary time t″ between t and t′, and hence to the event comprising the totality of states of the small region between t″ and t′. And from this it follows *a fortiori* that there is a strict deterministic law relating some event comprising states of the large region in some interval containing t to the event occupying the small region. Thus we can construct predictive maximally detailed strict deterministic laws relating temporally extended events so long as there is a time at which every point absolutely preceding some part of the effect is part of the cause. Now again we may divide up the large region into a foreground and background and produce laws of the form (P3) relating temporally extended events. But as before this choice of foreground and background regions will be completely unconstrained so that we cannot use such laws to distinguish events which cause a given effect from events which merely absolutely precede it. Nor can we accomplish this by relaxing some of the detail in these laws, for the same reasons as we encountered in the case of laws relating instantaneous events.

I conclude that of all the kinds of predictive strict deterministic law that are possible, none relate events to a non-arbitrarily selected part of what absolutely precede them. Arbitrary selections can be made on the basis of a spatio-temporal relation—in (P3), for example, the events related are taken to occupy the same spatial region at a temporal interval ε apart. But such laws cannot be used to distinguish the familiar notion of causation from absolute precedence, since that distinction cannot be specified solely in spatio-temporal terms.

Assuming that the fundamental physical laws are time reversal invariant,[11] it will follow analogously that causation and absolute precedence cannot be distinguished by means of strict deterministic retrodictive laws. For given an F-type event occupying a small spherical region of radius r* at (p,t), there may exist a maximally detailed strict deterministic law allowing it to be retrodicted at (p,t+ε) of the following form:

(R3) $(p)(t)(x)((L^{\#}(p,t+\varepsilon) \,\&\, Gx \,\&\, C(x)=(p,t+\varepsilon)) \rightarrow (\exists y)(Fy \,\&\, C(y)=(p,t)))$

where '$L^{\#}(p,t+\varepsilon)$' assigns some property to the large spherical region of radius $r^{*}+c\varepsilon$ (omitting the small spherical region of radius r) and centre (p,t+ε), and the remaining symbols are as in (P3). But similarly it can be shown that division of the consequent region in (R3) into foreground and background is arbitrary, and that none of the strict deterministic (R)-laws that may exist relate events to non-arbitrarily selected parts of what absolutely follow them.

IV

I turn now to consider a particularly influential view of the relation between singular causal statements and strict deterministic laws, that advanced by Davidson as The Principle of the Nomological Character of Causality (the PNCC)—events related as cause and effect fall under strict deterministic laws.[12] The first task of this section is to spell out what it is for a pair of events to fall under a law or laws. Then I shall use the results of the previous section to show that all pairs of events <a,b> fall under a strict deterministic law, if any pairs do, provided that the events have fundamental physicalistic descriptions and that a absolutely precedes b. This will serve to show, slightly more formally, that no analysis of singular causal statements in terms of strict deterministic laws can distinguish events which cause b from events which merely absolutely precede b. And it will strengthen the argument of the previous section for anyone who believes that although there aren't any (P)- or (R)-laws that relate events to non-arbitrarily selected parts of what absolutely precede or absolutely follow them, a distinction between causation and absolute precedence could still be made, given a suitable formulation of 'falls under' in terms of both (P)- and (R)-laws.

Various promising formulations of what it is to fall under a law fall foul of certain logical problems. Consider, for example, the following: <a,b> falls under a (P)-law iff the existence of a can be demonstrated in the light of such a law to be a sufficient condition of the existence of b. A first logical problem is that the existence of a can be shown sufficient for the existence of b simply by describing a as (ιx)(x=a & b exists). If we try to block this by demanding that the demonstration of sufficiency make essential use of the law, we may describe a as (ιx)(x=a &((P3)→ b exists)).[13] A simple and natural way to block these descriptions would seem to be to bar descriptions of events whose satisfaction assumes the existential statement which is to be derived. But I have found no non-question-begging way of characterizing 'assumes the existence of b'. A related logical problem is that of parasitic satisfaction by arbitrary events: Given any pair of events <a,b> which falls under a (P)-law according to the above formulation, the existence of an arbitrary event c can be shown sufficient for the existence of b by describing c as (ιx)(x=c & a exists).

Although Davidson has drawn our attention to the problem of parasitic modified this slightly.)[16] His formulations of the (R)- and (P)-laws[17] contain an unanalysed causal relation between events (hence his term 'causal laws') in order to mark the difference between lawlike and merely accidental generalizations, and also to effect the derivation of the singular causal statement that is demanded on this particular way of spelling out 'falls under'. So this formulation could not be developed into an analysis of singular causal statements. Davidson explicitly rules out this possibility of analysis on account of the problems of quantification over expressions of an unspecified language, and of restricting the descriptions of events so as to block parasitic satisfaction of the relation by arbitrary events.[18] Again, I do not think that parasitic satisfaction is actually a problem for this formulation of 'falls under', which demands the derivation of the singular causal statement. But a further problem arises in that both (R)- and (P)-laws are required in this derivation, which means that the same predicates 'F' and 'G' would have to be used in both laws. But, as we have seen, there can be no such pair of strict deterministic laws that are unqualified or operate under the same background conditions which use the same predicates (applying to events occupying small regions). So the condition would not be satisfied by any singular causal statements (relating events occupying small regions).

There are further ways of formulating 'falls under' but I do not think these lead to different results. For example, one could remove the requirement of uniqueness from the event descriptions, or add it to the existential quantifier within the laws, or one could descend a semantic level and talk of events and properties instead of descriptions and predicates, but none of these will provide a stronger condition. One could demand that the predicates featuring in the laws be the same as those appearing in the singular causal statement, but this would clearly lead to too strong a necessary condition for the truth of a singular causal statement. One could demand that the predicates featuring in the laws be ordinary language predicates (or at least not be complete physicalistic predicates), but as I have argued, there will be no strict deterministic laws of this kind.

By examining what kinds of strict deterministic law there may be, and by narrowing down the possible formulations of 'falls under' to those given by way of laws of the form (R3), I claim to have shown that all pairs of events <a,b>, where a absolutely precedes b, fall under strict deterministic laws, provided that (i) fundamental physicalistic laws are deterministic, and (ii) all events have descriptions of the form '(℩x)(Fx and C(x)=(P,T))' where 'F' is a complete physicalistic predicate, i.e. all events have complete physicalistic descriptions.

But with regard to requirement (i), the prospects for fundamental deterministic laws are bleak. At present quantum theory is well-entrenched as an indeterministic theory, with little to favour the case for a more fundamental deterministic "hidden variables" theory. What is less frequently realized is that quantum theory rules out the possibility of fundamental deterministic retrodictive laws. Radioactive decay provides a good example of apparent unpredictability, thus making the absence of predictive deterministic laws seem plausible, but it does not do the same for retrodictive laws. The only types of strict deterministic law compatible with indeterministic fundamental laws are conservation laws and deterministically interpreted statistical laws. But neither of these could serve to distinguish causation from absolute precedence, as they hold only in closed systems.[19] So if (i) is false, no pairs of events fall under strict deterministic laws. This allows us to modify the conclusion of the previous paragraph to say that all pairs of events <a,b>, where a absolutely precedes b, fall under strict deterministic laws, if any do, provided that condition (ii) holds.

I would like to note, in passing, that this poses a problem for Davidson's argument for anomalous monism presented in 'Mental Events'.[20] For if, as seems most likely, condition (i) is false, then the PNCC, which is a premise of that argument, will be false. And if (i) is true, then the argument faces a threat of circularity. For if (i) and (ii) could be independently established then it would follow that any pair of events <a,b> in which a absolutely precedes b falls under a strict deterministic law, and the PNCC would follow *a fortiori* from this. But if, as seems likely,[21] this is the *only* way the PNCC can be supported, then as condition (ii) entails a physicalistic version of the thesis of monism which appears in the conclusion of Davidson's argument, the argument becomes circular as soon as it is fortified with support for this premise.[22] The argument succeeds in showing the conclusion compatible with the premises, but its conclusion appears more plausible than at least one of its premises.

I conclude that there is no necessary or sufficient condition for the truth of singular causal statements in terms of strict deterministic laws that does not hold also of singular statements of absolute precedence, and hence that what distinguishes what causes an event from what merely absolutely precedes it has nothing to do with strict deterministic laws. Furthermore, I do not think that by weakening the requirements of strictness, determinacy, or lawlikeness, one could produce a successful analysis. For I argue elsewhere that there is nothing to distinguish what causes an event from what merely absolutely precedes it, other than considerations such as the beliefs and interests of the speaker and enquirer, so that we would not expect to find an analysis in terms of objective, non-interest-relative, notions making out causation to be any narrower than absolute precedence.

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NOTES

[1] I'd like to thank Donald Davidson and George Myro for prolonged help and inspiration in writing this, as well as Bruce Vermazen, Kirk Ludwig, Dugald Owen, Tony Dardis, Stephen Yablo, and James Woodward for valuable comments on earlier drafts.

[2] Another way of describing this is to say that a lies within the light cone having b as vertex. I say '*absolutely* precedes' since events a and b are indeterminate with respect to time order when a lies outside the light cone having b as vertex. So it is only when a lies within the light cone having b as vertex that a precedes b for all choices of time axis. See, e.g., Hans Reichenbach *The Philosophy of Space and Time*, section 22.

[3] The same dubious status attaches to laws which could be derived from these stating that whenever the phenomenon (e.g. the striking of a match) occurs between times t and $t+\varepsilon$, then some state or fact that an event has occurred (e.g. the match has ignited) obtains at some time after $t+\varepsilon$.

[4] Not all properties will do. If 'K' and 'L' indicate the size, shape and orientation of the region but nothing which happens in it, statements of the form (P1) should be counted not as laws but as expressing conceptual truths about space and time.

[5] The centre of the region could have been absorbed into the property as in (P1) but I have found it clearer to separate them. In Davidson's formulation of laws on p. 158 of *Essays on Actions and Events* (Hereafter: EAE) he incorporates the spatial location of the events into the predicates 'F' and 'G' and treats the time at which they occur by way of the function 't'.

[6] The distribution could be given by presenting each parameter as a function of position within the region, e.g. '$K^{\#}$' could be '$A=1-s$, $B=2s$, $C=1/s$, for $0 \leq s \leq r$', where A, B, and C are the parameters, and s is the distance from the centre of the sphere.

[7] Note, however, that the background conditions in the case of these laws are specified with very great detail so that the chances of these conditions cropping up are relatively remote. Thus they are unlike background conditions in the usual sense of the term.

[8] Provided the points specified in the antecedent absolutely precede those specified in the consequent.

[9] Laws of the form '$(x)(Sx \rightarrow Ox)$' seem uncontentious, so long as 'O' expresses an intrinsic property of the thing. It would be hard to see how two events identical in their physical makeup could differ in respect of their satisfying such ordinary language predicates as 'is a fire', 'is loud', 'is the occurrence of pain'. But in general there will be no laws in the reverse direction, i.e. of the form '$(x)(Ox \rightarrow Sx)$'.

[10] Assuming that the fundamental parameter can take indefinitely large values (as does mass, but not spin).

[11] The direction of time is marked by a time reversal asymmetry in the second law of thermodynamics, but this is not a fundamental law.

[12] See EAE pp. 160 and 208.

[13] Stephen Yablo pointed this out to me.

[14] EAE p. 158.

[15] (ii) is actually stronger than the condition required—that all events entering causal relations have complete physicalistic descriptions—but it follows from this given the uncontentious assumption that all events enter causal relations.

[16] EAE pp. 159-160.

[17] EAE p. 158. He labels these (N) and (S). (N) shows causes necessary for effects and hence (barring backwards causation) is an (R)-law. (S) shows causes sufficient for effects and hence (barring backwards causation) is a (P)-law.

[18] EAE p. 160, note 8.

[19] For example, fundamental indeterministic laws might give only the probability of a particle having a kinetic energy within a certain range, but a deterministic statistical law giving the mean kinetic energy of a large number of particles could still be possible if the mean kinetic energy of the particles in the system is construed as a parameter in its own right. And a conservation law derivable from this would give the total kinetic energy of the particles within the system. Such laws hold only in closed systems, i.e. they must relate states of the whole universe. We cannot start to derive smaller scale versions of them, as before, by restricting the consequent to a small region and the antecedent to a time slice of the light cone which has that small region as vertex, unless the statistical parameter or parameter to be conserved is some kind of construction from *all* the fundamental parameters. One could not construct a conservation law relating just some of the parameters as there would be no way of identifying some small region in which these parameters are to be conserved.

[20] The argument appears on p. 224 of EAE.

[21] The only arguments I know of for this apply to laws in general rather than to strict deterministic laws. They are Kantian attempts at transcendental argument, such as those offered by Kant himself, and the reconstructions of them given by Bennett and Strawson. I am inclined to accept the conclusion Mackie reaches in Chapter 4 of *Cement of the Universe* that none of these come close to success.

[22] My discussion here applies just to deterministic laws, though Davidson claims in a footnote to the PNCC that 'the stipulation that the laws be deterministic is stronger than required by the reasoning, and will be relaxed' (EAE p. 208). I have been unable to locate further mention of this. (Furthermore, if supervenience laws of the type '$(x)(Fx \rightarrow Mx)$' exist, where 'F' is as before and 'M' is 'is the occurrence of pain in a spherical region of radius r^{*}', then there will be no ruling out laws of the form (P3) where 'Mx' is added as a conjunct in the antecedent of the conditional. This falsifies one of the premises of Davidson's argument—that there are no strict deterministic psycho-physical laws—unless we construe the mental as restricted to the intentionalistic.)