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EXPLANATION AND LAWS

0. INTRODUCTION

In this paper I examine two aspects of Hempel's covering-law models of explanation. These are (i) nomic subsumption and (ii) explication by models. Nomic subsumption is the idea that to explain a fact is to show how it falls under some appropriate law. This conception of explanation Hempel explicates using a pair of models, where, in this context, a model is a template or pattern such that if something fits it, then that thing is an explanation. A range of well-known counter-examples to Hempel's models has led his successors to seek alternatives. Problems with limited amendments have encouraged some theorists of explanation to abandon nomic subsumption. So, in particular, *causal* components have come to be regarded as essential, even though Hempel had intended his model to capture causal explanation as well.[1] Here I want to examine the prospects for retaining nomic subsumption by rejecting the other feature of Hempel's approach – explication by models. An examination of the counter-examples will suggest that it is a mistake to imagine that a limited quantity of information about laws and antecedent conditions will be able to provide an actual explanation – other information, about explanations, may be relevant. This in turn leads me to examine what I shall call *structural* approaches. They are structural because the status of something as an explanation depends on its fitting into a structure of explanations. There are two structural approaches I shall examine. One is *holistic* – it proposes that we consider explanation hand-in-hand with the concept of law. This account of explanation inherits its holistic nature from the holistic (or *systematic*) character of laws of nature. The second *supervenience* view I shall consider is not global as the holistic approach is. Instead it concentrates on the 'vertical' structure of explanations, whereby the existence of a nomic explanation at one level reflects explanations on lower levels on which it supervenes. These structural approaches were first proposed in Bird

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(1998). Here I consider their limitations, in particular those concerning the holistic approach.

1. HEMPEL'S COVERING LAW MODEL AND ITS PROBLEMS

We start with Hempel's familiar covering-law model, in its D-N (deductive-nomological) form. The following comprises a complete explanation:

(M)	*Laws*	$L1, L2, \ldots, Ln$
	Conditions	$C1, C2, \ldots, Cm$
	entail	———————
	Explananda	$O1, O2, \ldots, Ok$

In this explanation $O1$, $O2$, ..., Ok are the phenomena requiring explanation (the explananda). What does the explaining, the explanans, consists of (i) $L1$, $L2$, ..., Ln which are the various laws used in the explanation, and (ii) $C1$, $C2$, ..., Cm which are the circumstances or conditions surrounding the explananda. The explanans must entail the explananda. (Hempel regards the entailment as holding between *statements* of laws, conditions and explananda, while I shall understand the relation as holding between *facts*.)

Let us say we want to explain certain facts:

(a) the fact that Mr Smith died;
(b) the fact that the pressure of gas in a certain syringe increased by 50%; and
(c) the fact that the bob of pendulum was traveling at 2 ms^{-1} at it lowest point.

These all have Hempelian explanations. So, in the case of (a) Smith's death is explained by the law that anyone who ingests a pound of arsenic dies within 24 hrs and the fact that Smith did ingest a pound of arsenic, viz.

(A)	*Law*	Everyone who eats a pound of arsenic dies within 24 hours
	Condition	Smith ate a pound of arsenic
	entail	———————————————
	Explanandum	Smith dies within 24 hours

And in the case of (b), the change in pressure P is explained by reference to Boyle's law, and the fact that the volume V was decreased by one third, due to the plunger being depressed.

(B)	*Law*	Under conditions of constant temperature, PV constant
	Conditions	the temperature remained constant
		the volume decreased by one third
	entail	———————————————
	Explanandum	the pressure increased by 50%

In the case of (c) we explain the velocity of the pendulum bob by subsuming it under Newton's laws of gravity and motion, and in particular the law derived from them, that the horizontal velocity V of a bob released from a height h above that point, under local gravitational acceleration g is given by $v = \sqrt{2gh}$

(C)	*Law*	$v = \sqrt{2gh}$
	Conditions	$g = 10 \text{ ms}^{-2}$
		$h = 0.2 \text{ m}$
	entail	—————————
	Explanandum	$v = 2 \text{ ms}^{-1}$

These examples, while they illustrate Hempel's covering-law model, also allow us to find counterexamples to it. By analogy with first the explanation (A) of (a), Smith's death, it seems we can also explain Jones's death in the same way since he too died within 24 hrs of taking arsenic.

(A*)	*Law*	Everyone who eats a pound of arsenic dies within 24 hours
	Condition	Jones ate a pound of arsenic
	entail	———————————————
	Explanandum	Jones dies within 24 hours

However, in this counter-example, which is due to Peter Achinstein,[2] we are further informed that Jones was hit and killed by a bus before the arsenic could kill him Thus, although each line of (A*) represents a fact or law so that the whole conforms to (M), the whole does not represent a genuine explanation.

Well-known too, is that a counter-example along related lines can be constructed from (B). Consider the same syringe whose plunger is being pressed. The following is a sound entailment regarding it:

(B†)	*Law*	Under conditions of constant temperature, $PV = k$
	Conditions	the temperature remains constant
		the pressure increased by 50%
	entail	————————————
	Explanandum	the volume decreased by one third

Since we have a law and conditions true of the syringe which entail the decrease in volume, we have constructed something which according to Hempel's account is an explanation. Yet we know it is not, since we know that the change in volume explains the change in pressure, not vice-versa. Nor can we save the model simply by building an asymmetry into the law, since there are situations for which the structure in (B†) does reflect a genuine explanation. Take a balloon filled with air and submerge it in water. The deeper the balloon is taken the greater the pressure. The volume occupied by the balloon will consequently decrease. This is then a case where a change in pressure causes a change in volume. What this seems to show is that we cannot tell whether a purported explanation is an explanation just by looking at its components and their relation. Correspondingly, for the balloon, the following:

(B^*)	*Law*	Under conditions of constant temperature, $PV = k$
	Conditions	the balloon's temperature remained constant
		its volume decreased by one third
	entail	————————————
	Explanandum	its pressure increased by 50%

is a sound argument, just as it is in (B), but does not constitute an explanation, since for the submerged balloon it is the change in pressure which explains the change in volume.

Similarly, consider a pendulum which starts with the bob hanging vertically. The bob is rapidly accelerated to 2 ms^{-1}. (Think of Newton's cradle when the impulse from one pendulum bob causes the motion of its neighbour). It then rises to a height of 20 cm above its starting point. (C^*) below, is identical to (C), but whereas (C) was an explanation in the case of the pendulum which started at rest in an elevated position, (C*) is not an explanation in the case of the second pendulum, since the direction of explanation is reversed. However, since (C) satisfies Hempel's model, so does

(C*)	*Law*	$v = \sqrt{2gh}$
	Conditions	$g = 10\ \mathrm{ms}^{-2}$
		$h = 0.2\ \mathrm{m}$
	entail	———————
	Explanandum	$v = 2\ \mathrm{ms}^{-1}$

There are other criticisms of the covering-law approach and of the D-N and I-S (inductive-statistical, or probabilistic-statistical, P-S) models it encompasses. Be that as it may, the lesson I wish to draw from these counterexamples is quite specific. The counter-examples (A*), (B*) and (C*) have been constructed so that the following is true: (i) they are (relevantly) identical to (A), (B) and (C) which correspond to genuine explanations; (ii) the statements of laws, conditions and explananda are all true; (iii) they do not correspond to genuine explanations; (iv) we know they do not correspond to genuine explanations because we are given further information that shows this.

Features (i) and (ii) mean that (A*), (B*) and (C*) *might* all have represented genuine explanations, since (A), (B) and (C) reflect genuine explanations. (A*), (B*) and (C*) all instantiate (M). Feature (iii) is what makes these falsifiers of Hempel's model. Hence satisfying (M) is not a sufficient condition of being an explanation, but, for all we have discussed, may yet be a necessary condition.

What I want to concentrate on is feature (iv). What tells us that (A*), (B*) and (C*) are not explanations is not any fact internal to (A*), (B*) or (C*). Rather it is additional information. Furthermore, in each case this information tells us what really explains the explanandum. in (A*) it is the bus which explains Jones's death, not the arsenic, in (B*) the balloon's change in pressure is explained not by the change in volume but by the increasing depth of submersion; in (C*) the velocity is explained not by the height the pendulum reaches, but by the impulse the bob receives. I will call the information regarding these facts the 'further defeating information' since it is what defeats the prima facie claims of (A*)–(C*) to be explanations.

Our counter-examples show that (M) fails as a sufficient condition of explanation, but not that it fails as a necessary condition. And so it is natural to ask whether further elements might be added to the model that might allow it to provide both a necessary and a sufficient condition. It would appear that this cannot be done in a non-question-begging way, if the problems just discussed can be generalized. This is because a natural approach would be to add a condition that would exclude cases (A*)–(C*) by excluding, in general, cases where there exist facts which constitute the defeating further information. But the relevant facts are facts about *explanations*. Hence any such extra conditions would compromise the status as a *model* of an amended (M) which included them. Let us say we devise a new model which is satisfied by a structure E, which we thus take to be an explanation. It might indeed be that E is an explanation; but it might also be that additional information shows that E is not an explanation, by showing that E's explanandum might be explained by something else, F. So, in order to determine whether E really is an explanation, we have to consider information regarding F. But what makes it that F too is an explanation or not an explanation? Presumably that F fits the model. But that is no guarantee as we have seen, unless we have further relevant information about possible explanations. This seems to involve us in an ever increasing search for information about possible explanations. The only way that this could be avoided is if the 'model' somehow made an implicit or explicit reference to all possible information. In which case the 'model' would no longer really be a model. Instead it will be a holistic account of explanation, since which explanations there are is determined by the same maximal set of information.

2. HOLISM – THE SYSTEMATIC REGULARITY THEORY OF LAWS

Hempel's approach to the explication of the concept of explanation takes the notion of law to be unproblematically antecedent to it. But it is at least doubtful whether he or anyone else is entitled so to do. For instance, it might be that our concept of law is to be explicated in terms like 'that which explains natural regularities'. If so, it would appear that the concept of explanation had better be antecedent to that of law. Something like this is indeed to be found in the accounts of law given by Armstrong (1983) and Tooley (1977). Armstrong and Tooley regard laws as second-order relations of necessitation among universals. I have argued against this approach in detail elsewhere (1998, 52–4), but in short the key problem lies in understanding the nature of the second order relation(s)[3] in question. An initially plausible approach is to regard these relations as theoretical entities, whose existence and instantiation *explains* the truth of corresponding universal generalizations. Thus this approach takes explanation to be conceptually prior to lawhood – the reverse of the relationship envisaged by Hempel.

Hempel himself favoured a regularity view of laws. Regularity views have their own problems. In particular, it must on any plausible view be true that laws may explain regularities and instances. Yet if laws just are the regularities, i.e., collections of instances, then this would require that laws explain themselves (or instances explain themselves). But on any view of explanation something may not explain itself.

Putting such objections aside, it is clear that the regularity view of lawhood should be more congenial to a Hempelian account of explanation. This is because regularity theories conceive of laws precisely as entities which deductively subsume particular facts. Most especially the systematic account of laws takes the role of laws to be the optimal set of regularities from which all particular facts are deducible. Hence, it would seem, this relation between laws and facts ought to be precisely the relation of explanation as conceived by Hempel. Therefore a close inspection of the concept of law, in the best regularity account, ought to help us solve the problems besetting Hempel's model. On the other hand, if no regularity view is able to support a Hempelian approach to explanation, that would be another reason for doubting regularity theories of law.

So let us look at regularity accounts of lawhood. Any regularity theory must deal with the fact that not every regularity is a law – the problem of accidental regularities. Say, for example, that it is true of everyone on a certain bus at a particular time that they ate Italian food in the following 48 hrs. While there is a regularity here we would not conclude that there is any corresponding law. Or to take an example of a kind discussed by Hempel and Reichenbach, it may be a regularity of nature that there are no persisting 1000 tonne lumps of pure gold, but that is no law, while it is a law that there are no persisting 100 kg lumps of pure or nearly pure uranium-235 (since the latter is fissile). The problem of accidental regularities is dealt with by a systematic approach to a regularity view of laws, of which the leading example is the Ramsey–Lewis account:

(RL) A contingent generalization is a law of nature if and only if it appears as a theorem (or axiom) in each true deductive systems that achieves a best combination of simplicity and strength. (Lewis 1973, 73)

Here Lewis mentions two features of the deductive system (i) simplicity and (ii) strength. The question of what simplicity amounts to, and whether it can be understood in an objective non-contextual, non-anthropocentric sense, has been much discussed. I shall not go into it here. Ramsey himself mentioned only simplicity but not strength: the laws are the "consequences of those propositions that we should take as axioms if we knew everything and organized it as simply as possible in a deductive system" (Mellor 1980, 138). The logical strength of a proposition is a matter of its information content, or, to put it another way, the range of possibilities excluded by its truth. Thus, if the regularity is of the form $\langle$All Fs are Gs$\rangle$, we want F to be as inclusive as possible and G to be as specific as possible.

The conditions of simplicity and strength add to the primary requirement that the system capture all the facts. We need to be clear about this, especially as regards the conclusions I wish to draw about explanation. Looking at the quote from Ramsey, it might give the impression that every fact should somehow he integrated into the system so that it might be deduced from it. But on that view every fact would be a law of nature. Even if we look at Lewis' version which takes the laws to be the contingent generalizations deducible from the optimal system, it will be the case that from a system from which all facts are deducible, there will also be deducible not only laws but accidental contingent generalizations. Hence it cannot be that the system captures every fact in the strong sense that everything is deducible from it. Rather what is, or should be intended is this. Take the system* to be that simplest, strongest set of axioms from which everything is deducible. Then we can divide the system* into two parts, one consisting of generalizations, the other of particular facts. From this combination all facts are deducible, but only because of the inclusion of the particular facts which correspond to initial conditions. If we remove these from the system*, so we are left only with the generalizations, then this is the system referred to in (RL). These generalizations and their consequences are the laws of nature on a sophisticated regularity view.

This picture needs some further refinement. If, as we have reason to believe, the world is irreducibly indeterministic, then indeterministic events should not be deducible from any system*. (Any system* which succeeded in so doing would be extremely complex and would not contain what we take to be the probabilistic laws of nature.) Let me distinguish between worlds which are *deterministic* and those which are *quasi-deterministic*. In a deterministic world all facts are subsumed under some (set of) deterministic law(s) of nature. From the corresponding system* every fact will be deducible. In a quasi-deterministic world every fact is subsumed under either a deterministic law of nature or a probabilistic law. Facts stating the occurrence of indeterministic events will not be deducible from the corresponding system*, but facts about the *probability* of those events will be deducible. If we regard the world as at least quasi-deterministic, then in this weaker sense just explained, every fact should be captured in the system* (even if not deducible from it). If one thinks that the world might be neither deterministic nor quasi-deterministic, then one thinks that there may be events which ‘merely’ happen, without there being any law which says that this event must happen or that it might happen with some fixed probability. This would be a *non-deterministic* world. Some facts might simply be left out of the system* altogether for a non-deterministic world.

Someone who thinks the world might be non-deterministic but who prefers a systematic regularity approach to laws will not regard it as necessary that the system* capture every fact, but nonetheless desirable that it capture as many as possible. This desideratum of the system* I shall call *inclusivity*. On this view, the system* should manifest the optimal combination of three factors: inclusivity, simplicity and strength. If one operates under the constraint of quasi-determinism, then one must have inclusivity at 100% in any acceptable system*.

How does the systematic approach rule out the accidental regularities mentioned above? The standard reply is that adding the relevant regularities “All people who traveled on the number 38 bus along Shaftesbury Avenue at 12.30 p.m. on Thursday 6th August 1998 ate Italian food within the following 48 hrs” and “There are no persisting 1000 tonne lumps of pure gold” to a system of laws detracts from considerably from its simplicity while adding little to its strength. This seems to be what Armstrong takes to be the way the systematic theory deals with the problem of accidental regularities. Furthermore, Armstrong also seems to take the strength condition to concern the number of actual facts a generalization subsumes, rather than extent of the logically possible facts which can be subsumed under the law – i.e., he confuses strength and inclusivity. Armstrong raises the possibility of *nomological danglers*.

> The following seems to be a meaningful supposition. Given the co-instantiation of a complex of physical properties. P, Q, R, S, it is a law that a further property, E, emerges. This emergent law might be quite unintegrated with the other laws of nature. It might be a ‘nomological dangler’. Far from adding *simplicity* to the system of laws, the $(P, Q, R, S) \rightarrow E$ law would add complexity. Suppose further that the conjunction of P, Q, R and S is very rare in the history of the universe. The law will hardly add any *strength* to the system of laws .... Indeed the $(P, Q, R, S) \rightarrow E$ uniformity appears to be just the sort of uniformity that the Ramsey–Lewis theory of lawhood is designed to exclude. *Yet it might be a law* (Armstrong 1983, 71–2).

It seems from this passage that Armstrong takes the actual number of instances of the $(P, Q, R, S) \rightarrow E$ uniformity to be relevant to the strength of the system which contains it. But this is quite a different consideration from the logical strength of the information content of a generalization. I suspect that Armstrong thinks that the issue of the number of actual instances subsumed, i.e., inclusivity, is significant because he thinks that the world might be non-deterministic – there might be events subsumed under no law at all. If inclusivity is less than 100%, then any increase in inclusivity will also lead to an increase in strength (and a decrease in simplicity). However, if one does take the world to be at least quasi-deterministic (i.e., inclusivity must be 100%) then it is quite clear what to do with nomological danglers – the regularities must be included as laws. For if they are not there will be some facts of the form Ex which are subsumed under no law. Under the constraint of quasi-determinism we will have to find the simplest, strongest system which is able to subsume these Ex type facts, and this will likely be the $(P, Q, R, S) \to E$ regularity.

Let us return to the question, how does the systematic view rule out accidental regularities? It may well be true that adding accidental regularities detracts from simplicity more than they add to strength. But I think the regularity theorist has and needs a better approach. For, as Armstrong points out, we cannot be sure that there are no accidental regularities which add less to strength than they detract from simplicity. Imagine a world (such as the ancients or medievals may have imagined to be the case) which is not well integrated into a simple and strong system. Then a unifying but accidental regularity might well improve the system. However, this seems to be beside the point. Consider the regularity of the bus passengers who all eat Italian. What facts tell us that this is indeed an accidental regularity? The relevant consideration is that we expect for each individual to find an explanation independent of the bus, and hence that the regularity is just a coincidence. So Ms. Pirie has an Italian meal for lunch because she has a business lunch at an Italian restaurant chosen by her clients, Mr. Williamson eats pizza that night because he and his mates have agreed to have beers and a take-away to watch the UEFA Cup Final on the television, and Mrs. Foggo and her family eat Italian food every day. So if we find an explanation for each instance of the regularity which makes no reference to that regularity, then that regularity is redundant. It need play no role in subsuming the facts because the facts are already subsumed under other, independent laws. Accidental regularities are not needed for the basic job of capturing the facts – their instances are subsumed under other regularities, those which are the genuine laws.

Thus it seems that the proper approach to systematization is this. The system* is selected by maximizing the desiderata of simplicity, strength and inclusivity (the latter being at 100% for determinism and quasi-determinism). But inclusivity is not increased by capturing the same fact more than once. Indeed it is a desideratum that we should minimize the extent to which the same fact is captured in more than one independent fashion. This I shall call the *double-counting rule*. The double-counting rule can be regarded as an element of simplicity, in that it is a demand for parsimony in the system*.

3. HOLISM – LAWS AND EXPLANATION

In the previous section, I have described how I think the systematic regularity theory of laws should be understood. Being systematic, requiring consideration of all the facts that there are, it is clearly holistic. In this section I shall explain how this relates to holism about explanation. The issue of accidental regularities shows some similarity to the problem cases for explanation. For in the latter we decided that a fact was not explained by a law by seeing that it is properly explained by other facts, while in the former we saw that certain facts are not to be regarded as captured by an accidental regularity since they are already captured by other regularities, the genuine laws. While there is a similarity, these problems are not identical. For in the question of regularities, what is being decided is whether a regularity is indeed a law, while in the question of pseudo-explanations there is no questioning the law in the pseudo-explanation; it is part of the example that we accept the law as a law. There is a nonetheless a connection. For if every supposed explanation in which a certain law participated turned out to be a pseudo-explanation, then on the systematic view as here outlined, it would in fact be no law. On that view, a regularity only has a right to be a law in so far as it does some non-redundant work towards inclusivity.

To see the significance of this, and to spell out further what I mean by 'a law capturing a fact' or 'a fact being subsumed under a law', it is most helpful to consider matters using Ramsey's heuristic of an omniscient being who seeks to systematize all particular facts. Let us also recall Hempel's model (M), and let us call something which satisfies it a *prima-facie explanation*. (I shall use this to cover cases where the major premise is a regularity which is a candidate for lawhood.) With the requirement of inclusivity in mind, the omniscient being will seek to construct a system* such that for each fact there is a prima-facie explanation of it. The fact that a regularity R could be included, were it a law, in a prima-facie explanation of a fact F counts in favour of its being regarded as an actual law. But if fact F has an alternative, independent prima facie explanation, the support lent to R is correspondingly weakened, thanks to the double-counting rule. And if the latter is the case for every prima-facie explanation in which R could be involved, then that would be enough to exclude R from the system. Many systems* might be constructed in this fashion, and the one which contains the actual laws is that which has the optimal combination of simplicity and logical strength. Consider that system*. It was constructed by considering prima-facie explanations of all the facts. Some of these contributed to the construction of the system*. Those prima-facie explanations are genuine explanations.

Let us see how this deals with the cases we discussed above. First consider Achinstein's case of explanatory preemption. Both Smith's death and Jones' death are events which fall under the regularity: (a) all people who eat a pound of arsenic die within 24 hrs; Jones' death also falls under the regularity (b) all people hit directly by a bus traveling at 60 kph die within 30 minutes. Both regularities are laws. Deciding which one explains Jones' death is answered in the response to the following question. In determining that these regularities are laws, under which of them was this event subsumed when systematising all the facts there are? To decide that question, we need to look at further facts, concerning Jones' physiology. The regularity that all people who eat a pound of arsenic die within 24 hrs is a consequence of three regularities of the form: (i) ingestion of arsenic is followed by the functioning of enzymes, (ii) failure of enzymes to function leads to bodily organs to fail (iii) acute organ failure culminates in death. In Smith's case the events of his death instantiated these regularities, while in Jones' case they did not. So in Jones' case we do not regard his death as an event which should be systematised under (a) but instead as one which should be systematised under (b).

It appears that this holistic approach will help us deal with cases of symmetrical laws and asymmetrical explanation. Those cases had the following structure. There are laws $L(F, G)$ and $L(G, F)$, **a** is both F and G, and according to (M) there are explanations in both directions. Now think of the omniscient being who sees that there are regularities $R(F, G)$[4] and $R(G, F)$, both well-supported by other instances. The facts $F\mathbf{a}$ and $G\mathbf{a}$ both need to be captured by the system. There are two prima-facie explanations $[R(F, G), F\mathbf{a} \Rightarrow G\mathbf{a}]$ and $[R(G, F), G\mathbf{a} \Rightarrow F\mathbf{a}]$. They cannot be both actual explanations since that would violate the anti-symmetric property of explanation. So with these regularities taken to be laws we can capture one of $G\mathbf{a}$ or $F\mathbf{a}$ but not both. The prima-facie explanation $[R(F, G), F\mathbf{a} \Rightarrow G\mathbf{a}]$ will contribute to taking $R(F, G)$ to be a law, and similarly for the other prima-facie explanation. But we cannot have both providing actual support. So which (if either), does the omniscient being chose? Let it be that F and G each figure as the consequent in only two plausible regularities, the ones mentioned and the regularities $R(H, F)$ and $R(J, G)$, and also that $H\mathbf{a}$ but not $J\mathbf{a}$. In such a situation, the omniscient being has a choice of two prima-facie explanations for $F\mathbf{a}$, but only one prima-facie explanation for $G\mathbf{a}$. On the double-counting rule, there is no advantage in having $F\mathbf{a}$ subsumed twice. while inclusivity enjoins us to subsume $G\mathbf{a}$ somewhere. Hence the omniscient being will decide to subsume $G\mathbf{a}$ via the prima-facie explanation $[R(F, G), F\mathbf{a} \Rightarrow G\mathbf{a}]$. This rules out subsuming $F\mathbf{a}$ via $[R(G, F), G\mathbf{a} \Rightarrow F\mathbf{a}]$ and so to subsume $F\mathbf{a}$ we need $[R(H, F), H\mathbf{a} \Rightarrow F\mathbf{a}]$ to be a genuine explanation.

4. PROBLEMS FOR THE SYSTEMATIC ACCOUNT

On reflection, however, this will not do. The example assumes that the regularities which we have identified as basic are: $R(F, G)$, $R(G, F)$, $R(H, F)$ and $R(J, G)$. Note that as *consequences* of these regularities are the regularities: $R(J, F)$ and $R(H, G)$. Indeed, we could regard these two as basic along with $R(F, G)$ and $R(G, F)$ while taking $R(H, F)$ and $R(J, G)$ to be derived. In general, where there is a symmetrical regularity between F and G, any basic regularity featuring F can be replaced by one featuring G (and vice versa) with loss. Therefore, in any deterministic system we will not be able to ascertain the direction of explanation between two events of kinds linked by symmetrical regularities.

Matters are in some regards different when we turn to the probabilistic explanation of events. Firstly, the probabilistic case allows for screening-off. Thus in the pendulum case the height does not fully determine the maximum velocity. There is a chance of interfering events which might mean that the final velocity is something different. Therefore the direction of explanation is one where this possibility exists. Its existence will be dependent on other facts and other laws. Which fits with the holistic approach envisioned here. Secondly, on the view expressed here and elsewhere (Bird 1998, 77–9; Railton 1981), strictly speaking in such explanations it is not the event which gets explained but instead it is the fact of its having a certain chance of occurring. This means that there is no strict question of explanatory symmetry since event A may potentially explain the probability of B's occurrence and B may potentially explain the probability of A's occurrence, which is not symmetrical in the way that $\langle A$ potentially explains B and B potentially explains $A\rangle$ was. Nonetheless there remains an issue of explanatory priority at a fundamental level where the possibility of screening off need not exist. Let it be that A explains why B has a high probability of occurring. B occurs. We do not want it also to be possible that B's occurrence then explains A's chance of occurring. It is not clear whether there is anything in the systematic account of law which allows us to ascribe asymmetry of explanatory priority.

It is worth reflecting that the existence of a symmetric regularity between Fs and Gs, $\forall x(Fx \leftrightarrow Gx)$, delivers problems not only for an account of nomic explanation on the systematic regularity theory, but also for Lewis's account of causation. For there will be nothing to distinguish

F**a** causing G**a** from G**a** causing F**a**. Say we allow both the regularities $R(F, G)$ and $R(G, F)$ to be laws. In the actual world both F**a** and G**a** occur. Then, in the nearest possible world in which F**a** does not occur, G**a** does not occur. Hence F**a** causes G**a**. But it is also true that the nearest possible world in which G**a** does not occur, F**a** does not occur (in fact it is the same possible world). So G**a** causes F**a**.

Another response is to axiomatise the system* so that we have only the regularity $\forall x(Fx \rightarrow Gx)$. No other law will have G as a consequent. So it will follow that in a deterministic system*, $\forall x(Gx \rightarrow Fx)$ is true, though not a law. Arguably we may now have sufficient asymmetry for causation to occur in one direction. But there are several objections to this move. First, we can reaxiomatise the system without loss of simplicity, strength or inclusivity and have $\forall x(Gx \rightarrow Fx)$ as a basic law and replace F in every other law by G. On this axiomatisation we would have a different verdict on which fact explains which. Secondly, following on the previous point, Lewis wants to regard as a law only those regularities which occur in *all* optimal axiomatisations. Since each of the regularities fails to occur in one of the two axiomatisations, *neither* will count as a law. Thirdly, it seems both arbitrary and at odds with the deliverances of science to stipulate that there cannot be properly symmetrical pairs of laws.

5. EXPLANATION AND SUPERVENIENCE

If the systematic account of laws ultimately fails to deal with the cases of symmetry, was it a mistake to think of it as satisfactorily handling the preemption case? The answer is that the approach suggested is correct but no thanks to any special feature of the systematic theory of laws. We know that Jones did not die of arsenic poisoning because we know that he was killed by a bus. So it looked as if the way to discover whether one explanation is correct is to look to see whether there is an alternative explanation of the same event. But just as the systematic account does not help us rule out two events explaining one another, it does not rule out one event having two independent explanations (the double counting rule notwithstanding). So, knowing that he dies by being hit by the bus does not of itself, on the systematic view, rule out Jones' death by poisoning. The details which rule that out are the facts that the various laws of physiology upon which the law of poisoning by arsenic is supervenient are not instantiated by events in Jones' body.

So a necessary condition on an explanation is that it be supported by the instantiation of any laws upon which the laws in that explanation are supervenient. Let E be a proposed explanation satisfying Hempel's D-N model (M) employing a law L which is not itself a basic law but is derived from a set of more basic laws. Then for E actually to be an explanation, not only must E conform to the Hempelian model (M) but also every more basic law from which L is derived must be instantiated so as to support an explanation relevant to E. Let us call this modified account (M*). The additional requirement in (M*) is violated by the pseudo-explanation (A*) because the laws from which its law is derived are not instantiated in Jones' case.

Even this is not quite right. For we may imagine that a derived law is supervenient on a disjunction of lower level laws: $L(P, Q)$ because $P = F \vee G$ and $L(F, Q)$ and $L(G, Q)$. We would not require that both $L(F, Q)$ and $L(G, Q)$ be instantiated when $L(P, Q)$ explains why something is Q – we need only one or other to be instantiated. Let the law L be supervenient on laws $L_1, \dots, L_m$. The relation of supervenience may take different forms. The case just mentioned is of supervenience on a disjunction of laws, while the poisoning law was presented as supervenient on a conjunction of three laws. Thus an explanatory instantiation of the supervenient law will require instantiation of the subvenient lower level laws in a way that is appropriate to the form or structure of that supervenience. Let us call such an instantiation *proper instantiation*. This will contrast with improper instantiation, as in the case of Jones whose death instantiated the poisoning law but did not instantiate the lower level laws in the appropriate way. As described, not all laws on which L is supervenient need to be instantiated for L to be properly instantiated. Let us call any subset of $L_1, \dots, L_m$ whose collective instantiation is sufficient for an instantiation of L a *sufficient subvenient set*. So a law is properly instantiated iff there is some sufficient subvenient set all of whose members are instantiated (properly or improperly). Say some event E is subsumed under a law $L - L$ is instantiated. The question is whether this subsumption counts as an explanation. For it to be so there must be some sufficient subvenient set of *basic* laws, all of whose members are instantiated.

This supervenience approach maintains the subsumption element of Hempel's covering law model. In effect, it says that the model operates unconditionally at the level of basic laws, while it operates conditionally for higher level, derived laws. There its operation is conditional on its operating at the basic level and all the way up as well. This seems a plausible way of seeing what is going on in explanation and is clearly related to the idea that A is the cause of B only if there is a chain of causal links between A and B where the causal links are all basic At the same time, it is difficult to regard the supervenience approach as a model – it does not provide a template fitting which decides whether something really is an explanation.

Nonetheless, the supervenience approach is not the last word on explanation. It provides only further necessary conditions, not a sufficient condition for being an explanation. Let $L(F, H)$ and $L(G, H)$ both be basic laws, and it also be true that $F\mathbf{a}$, $G\mathbf{a}$, and $H\mathbf{a}$. According to the account just given, both $F\mathbf{a}$, $L(F, H) \Rightarrow H\mathbf{a}$ and $G\mathbf{a}$, $L(G, H) \Rightarrow H\mathbf{a}$ may be explanations of $H\mathbf{a}$. Nonetheless, it may be that in cases like this (which plausibly never exist at this level) it just cannot be the case that one is the explanation but not the other. More importantly, the supervenience account does not give an answer to the problem of asymmetry. Consider (B*) and (C*). Firstly, according to (C*) the maximum height explains the maximum velocity, whereas we know that the reverse is the case. The law $v = \sqrt{2gh}$ is derived from Newton's laws of gravity and motion and these are relevantly instantiated by the pendulum and its bob. So while in (A*) (Jones' death) the relevant lower level laws are not instantiated, in (C*) they are. Similarly, the basic laws from which Boyle's law is derived are also Newton's kinetic laws (as well as electromagnetic laws) governing the behaviour of gas molecules. Again, these laws are instantiated in a relevant way, even if we reverse the explanans and explanandum.

1. CONCLUSION

Problems with Hempel's covering law model should convince us that the simple logical relation of deductive subsumption under a law is not sufficient for explanation. The question is, what more is required? Here I have explored the idea that while the idea of subsumption is correct, whatever more we need to add cannot be included in a model. There seemed to be good reason to hope that the systematic regularity theory of laws might provide an answer. First, this is a holistic approach to laws, which would yield a holistic account of explanation – explaining why finding a model is impossible. Secondly, there are parallels between the issue of accidental regularities and the problem of 'false' explanations. Thirdly, and most importantly, the systematic approach works by seeking to subsume facts under laws in forming the optimal system. Since such subsumptions are constitutive of the laws in question, they must all be 'genuine' not 'false' (in the sense that Smith's subsumption under the poisoning law is genuine. but Jones' is false). And so they should correspond to instances of name explanation Nonetheless, even the titivated systematic account of laws lacked the resources to deal with the cases of symmetrical laws or pairs of laws. This should be looked upon as a failing of the systematic approach. Deductive integration is too weak a notion of 'genuine' subsumption, just as deductive entailment is too weak an account of explanation.

The discussion also reveals the differences between the cases of symmetry and preemption. Ordinary cases of the latter may be dealt with by a natural way of looking at the relationship between 'derived' laws and the basic laws upon which they supervene. Explanations employing derived laws must be reflected by appropriate instantiations by basic laws. We may be able to retain Hempel's guiding intuition that explanation is a matter of subsuming facts under laws, but we will have to reject both his preference for a regularity view of laws and his attempt to explicate explanation using a model.

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NOTES

[1] For causal theories of explanation, see for instance Ruben (1990), and Lipton (1991).

[2] See Achinstein (1983).

[3] Armstrong thinks of their being one such relation which occurs in all laws while Tooley thinks of there being a family of such relations.

[4] I will use $R(F, G)$ as shorthand for $\forall x(Fx \rightarrow Gx)$ etc.

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