13

Counterfactuals, numerical laws, and necessity-in-praxis

Had this essay been intended as an encyclopedic treatment of the analysis of physical laws, it would have had to touch upon many more topics. It was not my purpose, however, as I explained in the preface, to say everything that could be said, nor even everything that should be said. What I set out to do was to examine the differences between two theories. And I followed my own interests, with the result that some often-examined issues were relatively unexamined. I will, then, by way of concluding, examine three of these issues and offer a few brief comments.

I have, at several points in this book, discussed counterfactual conditionals. But I would like now to make a final observation about this class of propositions.

Suppose (adapting a famous example) that all the coins that ever were, are, or will be in my daughter Diane's piggy bank are copper pennies, and suppose that this bank has an individuating description, *XYZ,* in purely descriptive terms. Thus the universal generalization, that all the coins in an *XYZ* piggy bank are copper, is true. What, then, of the truth-value of the counterfactual conditional, "If a coin were to be added to an *XYZ* piggy bank, it would be copper"? The received answer is, "The counterfactual conditional is false, and this for the reason that the universal conditional is an accidental, not nomological, truth."

Regularists will reject the reason given for this latter answer. For a Regularist, there is no difference between accidental and nomological truths. But suppose a Regularist wants to agree that the suppositional conditional, namely, "If a coin were to be added to an *XYZ* piggy bank, it would be copper," is false. How shall he justify his choosing this truth-value?

I think that the warrant for that particular answer is easier than it is usually portrayed to be. The Regularist says that the counterfactual is false simply because not all piggy banks contain only copper coins. But why invoke a truth about *all* piggy banks rather than about the restricted class of *XYZ* piggy banks?

The proper answer to *this* latter question is, I admit, very difficult to formulate. But I do not have to be able to give it to be fairly sure that the immediately preceding justification for the Regularist's choice is right. Indeed, I am certain that it is this latter fact, about *all* piggy banks, that Necessitarians also really appeal to when *they* deny the truth of the counterfactual conditional.

I propose an experiment. Ask a Necessitarian *why* it is false that, were a coin to be introduced into an *XYZ* piggy bank (which never contains anything but pennies), that coin would be copper. At first, the answer might be: "Because although it may be true, it is not *nomologically* true that all coins in an *XYZ* piggy bank are copper." Persist. Ask now *why* he thinks the universally true proposition about *XYZ* piggy banks is not nomologically true. Now the answer will be: "Because not all piggy banks contain copper coins; some contain other kinds of coins as well: nickel, silver, aluminum, gold, etc." But having eventually arrived at this claim about other piggy banks, it seems to me that the Necessitarian's intermediary stage of invoking a nomological necessity (or rather the fact of the absence of such a necessity) is, if not gratuitous, at least dispensable. For the latter claim, about other piggy banks, could have served directly rather than mediately as the explanation of the falsity of the counterfactual conditional.

Appearances to the contrary, this argument just given does not depend on the relation between explanans and explanandum being transitive. The statement "*p* explains *q*" (where *p* and *q* stand for propositions) is a nontransitive relation. The argument is *not*:

> "Not all piggy banks contain copper coins" explains "it is not nomologically true that all coins in an *XYZ* piggy bank are copper"; and hence, by transitivity, the former universal proposition explains why the counterfactual about *this* silver dime is false.

No, my point is that the apparently mediating claim about nomicity is elliptical for the denial of the nonmodal universal generalization. The falsity of the universal generalization explains the truth-value of the counterfactual directly. The introduction of the concept of nomicity is superfluous. Perhaps the concept of nomicity here plays some pragmatic role in discourse; but to admit this is not to be committed to saying that the necessity invoked need be thought to represent an ontological feature of the world.

The Necessitarian's test for nomicity, which would have it that only nomologically, but not accidentally, true universal generalizations will support a singular counterfactual proposition, seems not to work at all for the alleged parallel distinction between nomological statistical laws and accidentally true statistical generalizations. Consider the probabilistic counterfactual conditional, "If this film frame were in the world's most expensive camera, it would probably contain a latent image of a flyby picture of the surface of Venus." What grounds the truth of this probabilistic singular counterfactual? A statistical generalization of this sort: "Most of the film frames in the world's most expensive camera contain latent images of flyby pictures of the surface of Venus." Here it would seem that the statistical generalization invoked is, according to Necessitarian criteria, merely accidental. Yet this 'accidental' generalization *does* seem to support a probabilistic singular counterfactual.

There is a variety of responses the Necessitarian can make to this case, all of them, however, inimical to his position. He could try, for example, to argue (i) that no statistical propositions are physical laws. But – as I argued in Chapter 12 – quantum mechanics, at the very least, advances strong evidence that some are. Or he could argue (ii) that, inasmuch as the statistical generalization in this instance does warrant a singular counterfactual conditional, that generalization is a physical law (and is thus according to his account nomological). The trouble with this response, however, is that the generalization about the world's most expensive camera seems to share all relevant properties with those universal propositions that Necessitarians have held up as examples of merely true, accidental generalizations, for example, "All moas die before the age of fifty"; "All the screws in Jones's car are rusty"; etc. If he is not, then, to have to retract all his former examples, it would seem that the Necessitarian cannot deny that the generalization about the world's most expensive camera is merely accidental. Or finally, he might try to argue (iii) that in this example the statistical generalization (since it *is* merely accidental) does not in fact warrant the singular counterfactual. But here the reply is that the warranting relation in this case is as strong as in other examples usually adduced in these discussions. To deny it in this instance would be suspiciously ad hoc.

The upshot is that the Necessitarian's test using counterfactuals to distinguish between nomicity and accidentalness does not work. And the reason why, I suggest, is that it attempts to make a distinction where in fact there is none. There is no distinction because there are no nomological necessities: neither universal ones nor statistical ones.

Let's now turn to a second issue.

Sometimes Necessitarians have objected to the Regularity Theory on the grounds that the theory is unable to accommodate *numerical* physical laws. It is pointed out, truly, that not all – indeed very few – scientific laws are of the conditional form, $(x)(Sx \supset Px)$. Most scientific laws are, rather, propositions about relations between mathematical quantities, and, inasmuch as the class of scientific laws is a surrogate for the class of physical laws, the latter may also be supposed to be comprised of a vast number of numerical formulas. These latter physical laws are propositions about relations between mathematical quantities, and their variables range over a nondenumerably infinite domain of real, and sometimes imaginary, numbers. Propositions taking their truth from *actual* occurrences – the challenge goes – could never begin to cope with such domains. At best, physical laws, construed as statements about what actually happens, could be true for only a minute number of values encompassed by any one physical law. Necessitarianism is then offered as the corrective. (See Pap 1962, pp. 303-5.)

The correction is not needed. Regularity has no trouble on this score. One does not have to 'strengthen' the mode of truth of numerical laws. Suppose we construe numerical laws as compendia of an infinite number of singular statements (indeed, such a view is the favored contemporary explication of the mathematical concept of "function"), where the constants and variables in these statements stand for numbers and physical quantities. Suppose, for the moment, just to have an easy example, that Ohm's Law, that is,

P14 $IR = E$

were true. (I stands for the value of the current; R for the value of the resistance; and E for the value of the voltage.) The singular expansion (suitably defined) of this law comprises a nondenumerable infinity of propositions including, for example,

P15 *5.7893 amperes* $\times$ *45.2349 ohms = 261,878.40657 volts*

Now let's suppose, further, (probably not too unrealistically) that these particular values never are (at any time) instanced in the current, resistance, and voltage, respectively, of any actual electrical circuit.' What follows? Would the truth of this latter fact (i.e., the absence of instances) 'make' Ohm's Law false?

Hardly. Construed as a material conditional, *P15* would read thus:

P16 *If the current in an electrical circuit is 5.7893 amperes and the resistance is 45,234.9 ohms, then the voltage is 261,878.40657 volts*

P16, it is clear, is *true* if no circuit has a current of 5.7893 amperes, or if no circuit has a resistance of 45,234.9 ohms, or if no circuit instances both these values.

If anything, having noninstanced values of its variables enhances the probability of a numerical proposition's being true. But of course having noninstanced values does not guarantee the truth of a numerical proposition unless *all* its numerical variables go wanting for lack of an instance. One need not fear for Ohm's Law on this latter count. It is hardly vacuously true. Millions upon millions of its variables are instanced daily on this planet, blanketed as it is with electronic devices.

Consider, now, what would happen on this analysis to a 'pretender'-law. Suppose someone were to hypothesize (contrary to what we are here assuming to be true) that the relationship between current, resistance, and voltage is not as stated in Ohm's Law, but is rather as stated in Liar's Law, namely,

P17 $IR = 2E$

The singular expansion of this 'pretender'-law would include

P18 $5.7893 \text{ amperes} \times 45{,}234.9 \text{ ohms} = 2 \times 130{,}939.203285 \text{ volts}$

Presuming, as above, that no circuit instances both these first two values, *P18*, like *P15*, will turn out to be true. But this does not mean that the 'pretender'-law, *P17*, also turns out to be true. *P18* is merely one among an infinite number of necessary but insufficient conditions for the truth of *P17*. And some of these other conditionals in the singular expansion of *P17*, rather than being vacuously true, will (assuming it is Ohm's Law that is *true*) be determinately false. In short,

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1 Should anyone think that these values might realistically be actually instanced, then construct a new example by increasing each of these figures by a factor of 10^{18}, 10^{21}, and 10^{39}, respectively. One will not find these latter values in this world.

having 'gaps' in the data base (i.e., not having actual instances for every logically possible solution of the numerical equation) does not mean we are saddled with Liar's Law.[2]

But gaps do present other problems. For any distribution, whatsoever, of graph points, provided that distribution is finite or denumerable, there will, theoretically, be an infinite number of *different* equations (curves) all fitting this set of points *perfectly*. If our data base is not mathematically continuous – and how could it be? – there will be an infinite number of different numerical laws all subsuming those data. No matter how many would-be 'laws' (curves) are (timelessly) eliminated by our future fillings-in of more and more gaps, (timelessly) there will always be an infinite number of different (i.e., logically nonequivalent) physical laws, each subsuming the totality of the actual past, present, and future gappy data.[3]

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[2] I have just given "data base" a specialized definition. Here and below, by "data" I do *not* mean "data gathered"; I mean, rather, "the *actual* instances (whether known or unknown) of the logically possible solutions to a physical law." I.e., "data" designates an ontological, not an epistemological, category. I regret having to distort the standard meaning of a common term, but I do not know of any other term that precisely embodies the sense I need here.

[3] Serendipitously, just a few weeks after I had written the above paragraph, my daughter came to me with a problem she was having in her junior high school math book (Sobel and Maletsky, 1974, p. 72). The students had been given the task of finding 'the' formula that fills the gaps in the following mapping:

x	y		z
3,	4	$\mapsto$	5
6,	8	$\mapsto$	10
9,	12	$\mapsto$	15
5,	12	?	?
16,	12	?	?
20,	15	?	?
8,	15	?	?

Diane could not figure out why the book gives as the 'official' answer "$z = \sqrt{x^2 + y^2}$" when she found another formula that equally well fit perfectly the first three (completed) entries in the table. Indeed, in just a few minutes, she and I found three solutions, all in some sense simpler than the official one:

$z = 2y - x$
$z = 3x - y$
$z = 5(y - x)$ *[footnote 3 continued on p. 192]*

Is the situation tolerable? We know what many persons have said about this plethora of equations all fitting the data: "Truth is simple; whichever of these is simplest, that is the true one." And, "Necessity is reflected in the ease with which the proposition may be incorporated into the corpus of science."

The reply is that these latter kinds of answers are misdirected. What persons who invoke *simplicity* as a criterion of acceptability are doing is not proposing a metaphysical test for nomicity, but a methodological rule for getting on with the job of predicting, explaining, and controlling the world.

Admittedly, this view – that all equations that fit the data, however different they may be from one another in their predictions of (timelessly) uninstanced values, are all laws – is at odds with the established view. Indeed, even most Regularists, too, probably believe that there is but *one* law, however complicated, that describes, for example, the interrelationship among the values of current, resistance, and voltage in all electrical circuits. But I think the Regularity Theory demands, and I cannot see that there would be any theoretical problems whatever in allowing, that there are as many laws as there are true propositions, each of which subsumes all the actual data, past, present, and future. Goodness knows we would not want to cite some of these laws in our day-to-day designing of electrical circuits – some of these laws are horrendously complicated, running on to miles of paper were we to try to express them in ordinary-sized type, for example – but they are laws nonetheless. Again, my point is the earlier one, that physical laws, construed as true descriptions of the singular facts of the world, must be distinguished from what are *used* as laws in scientific practice. (Also see Cartwright 1980b.)

One can imagine that a Necessitarian will want to bestow special status on one alone of these many equations, each of which fits the data:

> One of these propositions is necessary: It alone would fit all those possible data that are never actualized. Were the gaps to be filled in, all but one of these equations would be eliminated, and that one is the nomologically necessary one.

[cont.] Obviously, each of these latter formulas gives quite different sets of values for the completion of the third (z) column.

The relevance, to my discussion above, of this exercise is clear: There is no such thing as a unique curve fitting any finite set of points. As to the opinion one should form of my daughter's mathematics text, decorum forbids an explicit suggestion.

The Regularist replies:

> Let me try one last time to challenge your views. Clearly, you seem to think that one alone among this vast set of nonequivalent equations, all of which fit the gappy data, is nomologically necessary. It is that one that would be true if all the gaps were to be filled in.
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> But nomological necessity is not a determinate property of any member of this set. For there are as many ways to fill in the gaps as there are nonequivalent equations fitting the *actual* data. Every one, every last one, of all that infinite number of equations turns out in some possible world or other to be *the* one that fits the filled gaps. That is, every possible way of filling those gaps is realized in some possible world or other. And because those gaps, ex hypothesi, are not filled in this world, no determinate sense can be made of the supposition that this world is exactly one of those worlds and not another. Indeed, the one thing we must say is that this world is none of them. This world is not a world in which there is a single mathematical solution to the actual data.
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> Each world in which the data are complete, that is, without gaps, is blessed with a single law subsuming those data. But this world is not so blessed; and we just have to put up with having many logically nonequivalent laws all subsuming the same data.
>
> To attribute nomological necessity to a proposition in this world is to suppose that certain propositions have a determinate property that, logically, they could not have. And to attribute nomological necessity to a proposition in a world blessed with gapless data is to say nothing more or less than in that world no other nonequivalent proposition subsumes those data.

The Necessitarian counterargues:

> I am glad you have invoked talk of possible worlds. My point can be put very nicely in terms of possible worlds. As you say, in this world the data base is gappy. There is an infinity of different possible ways those gaps might be filled in.
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> But of course, in other possible worlds, these different possible ways are realized. In some possible worlds, the gaps are (partially or wholly) filled in one way, and in other possible worlds, the gaps are (partially or wholly) filled in other ways. Some of these nonactual possible worlds will be *physically accessible* from the actual world, others not. Consider the set of all those possible worlds that are physically accessible from this world. It is an infinite set. In each of these worlds (apart from the one in which the data base is completely filled in), there will be many, presumably infinitely many, formulas subsuming that world's own gappy data base. But there will be one formula, and one formula alone, *common* to all these worlds. And it is *that* unique formula that is the one that is nomologically necessary in this, the actual, world.

The Regularist has his last say in the matter:

> Talk of physical accessibility does not illuminate the matter in the slightest. It may give us a powerful heuristic method by which to conceive of these matters, but really it is just a translation, not an analysis, of the concepts at play here. Unless physical accessibility is to be some sort of intuitively comprehended primitive, *it* will have to be defined in terms of physical possibility, physical necessity, and the like. Or will it have to be defined in terms of nomological necessity? Either way, it will not ultimately solve the problems we have been addressing. It will only transubstantiate them.
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> Here in the actual world, we have, as it were, an embarrassment of riches: An infinity of nonequivalent formulas all subsume the gappy data base. We Regularists (some of us anyway) are content to accord to all these formulas the status of lawfulness. You want to single out one, known or unknown, as being 'the' physical law. It is that one alone, that, *were* the gappy data base to be filled in, would subsume all the instanced values. Clearly, this is what your possible-worlds story is designed to do; to give us a way of specifying truth-conditions for this latter counterfactual conditional.
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> But there is no good reason, whatever, to think that there is any one such favored solution. Why not simply allow that all formulas that fit the actual data are physical laws? Talk of physical accessibility and the like, although captivating, does not advance our ability one iota to distinguish one formula from another. It is a metaphysical distinction with absolutely no empirical manifestation. If it exists, it cannot – by its very nature – ever reveal itself to us empirically.
>
> Some persons have suggested that the mark of this nomological necessity is simplicity: that the one formula that is simplest, among all those that subsume the actual (gappy) data, is the one that is nomologically necessary.
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> The trouble with this notion is that, again, it fails to provide a decision procedure. "Simplest" is not a well-defined notion. Then, too, when in our actual practice we have chosen, using some convenient if somewhat arbitrary notion of "simplest," among a few ready-at-hand alternative formulas, it must be emphasized that these choices are not even between *true* statements. Virtually without exception, the various statements that get called "laws" in science are known to be false. Hence, they cannot be nomologically necessary. If simplicity were the hallmark of nomological necessity, again, we would have no idea when a statement satisfied that condition.
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> Ordinary practice knowingly selects false propositions as workaday laws. It can hardly, then, be trusted to provide a guide to selecting one genuine nomological from

> among an infinite host of other true statements. Indeed, even if all these true statements were – per impossible – to be known, we might still much prefer to *use* a false approximation than to be saddled with the burden of calculating with a nomological of complexity beyond practical utility. That is, even if nomological statements could be recognized, we might not want to use or invoke them in our doing science. They might be too complicated for our purposes.
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> In short, we are unable to analyze the concept of "nomological necessity," we have no way of recognizing nomologicals, and we probably would not want to use them if they *could* be recognized. Why, then, persist in the dogmatic, useless belief that they exist? The notion is at once idle and mischievous. Why not, finally, abandon it?

Although this latter exchange will close the discussion of numerical laws, it does not constitute quite the last word in the debate. In its course, this latest dialog has made reference to the practice of science. Might it be there, in what scientists do, rather than in what they examine, that one might find nomicity? One Necessitarian, Rescher, believes so.

In Chapter 6, we saw how Rescher argues that nomological necessity can never be "extracted from the evidence," that is, can never be revealed experimentally. Yet he remains sanguine about attributing nomological necessity to certain propositions. The passage quoted in Chapter 6 continues:

> Lawfulness is not found in or extracted from the evidence, it is superadded to it. *Lawfulness is a matter of imputation*. ... Men impute lawfulness to certain generalizations by according to them a particular role in the epistemological scheme of things, being prepared to use them in special ways in inferential contexts ...
>
> Lawfulness is not a matter of what the generalizations [*sic*] *says*, but a matter of *how it is to be used*. By being prepared to put it to certain kinds of uses in modal and hypothetical contexts, it is *we*, the users, who accord to a generalization its lawful status thus endowing it with nomological necessity and hypothetical force. Lawfulness is thus not a matter of the assertive content of a generalization, but of its epistemic status, as determined by the ways in which it is deployed in its applications. (Rescher 1970, p. 107)

The necessity Rescher would accord to physical laws is neither metaphysical nor linguistic, but epistemological. It arises out of the role physical laws play in our schemes of explanation. Much earlier in the same book, Rescher calls this property of physical laws their "coherence," but by the use of that term he does not mean simply *consistency* with one another or indeed even with the whole of the scientific corpus. Rather, he means the term to designate something stronger, what he also calls "integration into the body of scientific knowledge" (p. 16), that is, mutual support through interlocking deductive and inductive relationships. In short, "coherence" (in his specialized use), "lawfulness," "nomicity," and "integration" are all correlative terms. They connote a pragmatic aspect of select generalizations, an epistemic-cum-explanatory role in the scientific enterprise.

Rescher is certainly right in pointing out that what get used as laws by scientists in their giving of scientific explanations tend not to be 'isolated' propositions but those that 'fit' into larger schemes of theories. But the question we must ask is whether the distinction among universal and statistical generalizations – between those that get used as laws and those that do not – is the same distinction as that between nomicity and accidentalness. The answer will have to be: No. For when we examine Rescher's necessity-through-use, we find that it bears little resemblance to the traditional Necessitarian's nomological necessity and is ill-suited to offer the solutions Necessitarians have perennially demanded of nomological necessity.

The first, but by no means least, problem in Rescher's proposal to identify nomicity with elevated epistemic status in the scientific corpus is that nomicity has always been conceived to be a timeless property of propositions. In contrast, the body of scientific laws, that is, those propositions used by practicing scientists as laws, varies from time to time and, to a lesser degree, from place to place. Is nomicity thus to change, too, from time to time and place to place? Rescher is silent on this point. His theory seems geared to a static science rather than a dynamic one. But science is not fixed.

A nomicity that changes from time to time and place to place is totally unacceptable according to traditional Necessitarian accounts. After all, the nomological necessity of copper's conducting electricity is not supposed to be something that first occurred in the eighteenth century when conductivity was discovered. Copper is the sort of stuff that, if it conducts electricity necessarily, has *always* done so. But if the class of nomologicals is not to change in lockstep with the evolution of scientific practice, can we construct a timeless nomicity out of the flux of practice? The prospects are minimal. It will not do, for example, simply to say that a proposition is nomologically necessary if it is ever (in the past, present, or future) used as a scientific law and is not nomologically necessary if it is never so used or if it is firmly rejected as a law. The trouble is obvious: Many propositions that at one time are firmly entrenched as scientific laws (e.g., all flammable material contains phlogiston; all planets travel in circular orbits; electromagnetic radiation is a transverse wave propagated in a medium) are later just as firmly and resolutely regarded as nonlaws. A given proposition, then, might (timelessly) have contradictory properties, namely, being nomologically necessary and being not nomologically necessary. To construct a consistent, nonarbitrary theory of timeless nomicity, one would have to invoke a Science Completed. But were we to do that, we should never – because we cannot foretell the remote future developments of science – be able reasonably to regard ourselves as knowing of any proposition that it is nomologically necessary.

The difficulty with grounding a timeless necessity in the flux of practice is hardly the end of troubles. A second, no less serious, difficulty arises.

Can a nomological necessity, conceived to be an epistemological feature of propositions, assume the role that has traditionally been regarded as the preserve of an ontological necessity? Rescher writes as if it could:

> To explain a fact scientifically is thus to adduce reasons to show why *this* fact obtains rather than some one among its possible alternatives. This requires going beyond establishing that the fact *is* actually the case to showing that (in some sense) it *had to* be the case – that it was *necessary* and inevitable, that it should be so – or at least *probable* and "to be expected."
>
> ... Scientific explanation proceeds by *subsumption under laws*, by placing the item to be explained as a somehow special case within a framework of generalizations that are taken to state how things must operate within a certain range of phenomena (1970, p. 11)

Note the admixture in this passage of psychological terms and metaphysical ones: On the one hand, "to be expected"; on the other, "had to be the case," "inevitable," and "must operate."

It may be plausible to argue that the epistemic necessity of the generalizations we actually use in giving explanations accounts for our psychological expectations. To say that all *A*s are *B*s is epistemically necessary may be just another way of saying that a person who *knows* that this proposition is ‘integrated’ into the fabric of science *expects* all *A*s to be *B*s. Epistemic necessity and psychological expectation may well be closely allied. (Perhaps the connection is even analytic.) But psychological expectation is not metaphysical necessity. The shift between “to be expected” and “inevitable” is not, in this context, merely a shift between two psychological terms, but is also a shift between a psychological term and a metaphysical one. Throughout, the two categories – the psychological and the metaphysical – are confounded.

“Nomological necessity” or “theoretic coherence” in Rescher’s view arises out of the conscious, deliberate, rational practice of scientists. However he might choose eventually to explicate this notion, it is clear that it will have to be a relation one of whose terms will designate a set of persons, whether individual scientists, groups of them, or perhaps the entire scientific community. In any event, this explication of nomicity will have as a consequence that to attribute nomicity to a proposition is, at least in part, to say something about *us*. (Or, if not literally to *say* something about us, then at least to presuppose that our existence should *figure* somehow among the truth-conditions of that proposition’s being nomological.) Few Necessitarians have ever thought that the necessity of physical laws is a fact (however partial) about *us*. Consider Rescher’s own example: “All elms ... must shed their leaves in the fall” 1970; p. 11). Only Idealists and Pragmatists would think that this proposition was ‘about’ us as well as elms. Virtually everyone else would think that this proposition is not about us at all, but only about elms, leaves, autumnal days, and exfoliation.

Rescher is himself aware of the Idealist aspects of his theory and is forthright about them (Rescher 1970, section titled “Lawfulness as Mind-Dependent,” pp. 113-21):

1. The natural world comprises only the actual. This world does not contain a region where nonexistent or unactualized possibilities somehow “exist. “ Unactualized hypothetical possibilities do not exist in the world of objective reality at all.[4]

2. Nor do unactualized possibilities somehow exist in some Platonic realm of world-independent reality.

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[4] Contrast with von Wright: [*p* (a generic state of affairs) may be] “A potency or latent possibility of the world” (1977, p. 20). This later quotation, recall, was examined in the section titled “Actualized and unactualized dispositions” in Chapter 8.

3. The very foundation for the distinction between something actual and something merely hypothetically possible is lacking in a "mindless" world. Unactualized hypothetical possibilities can be said to "exist" only insofar as they are *conceived* or *thought of* or *hypothesized*, and the like. For such a possibility to be (*esse*) is to be conceived (*concipiendi*). (pp. 118-19)

Rescher obviously shares with the Regularist the inability to 'locate' nomological necessity *in re*. But, unlike the Regularist, he is not prepared to abandon the notion that physical laws are nomologically necessary. And thus he 'locates' the necessity in *us*.

> A [universal] generalization like "All cats are vertebrates (i.e. have backbones)" *if not taken to formulate a law* makes a claim whose correctness is doubtless unaffected if we postulate a mindless universe. But if the [universal] generalization is construed in a lawful sense, as asserting that cats *have to* have backbones, with some sort of nomic necessity the story is quite different. For lawfulness "lies in the eyes of the beholder," since the lawfulness of a [universal] generalization consists in its being treated and classified and used in a certain way. (1970; p. 116. Glosses added)

Could nomicity thus explicated, lying "in the eyes of the beholder," possibly do what Rescher requires of nomicity? Could it, for example, account for the modal aspect of the 'having to' in "all cats *have to* have backbones"?

The suggestion strikes us as implausible. All cats, to the best of our knowledge, have backbones. But whether they do or not has nothing to do with us, not even with our engaging in scientific research and theory construction. Although we may discover this fact about cats, surely it was 'there' antecedently to be discovered. Why should the case be any different when it comes to ascertain whether cats *have to* have backbones? Why should this be a question requiring for its answer a fact about us? Surely – like their having backbones – their *having to* have backbones, if indeed it is a fact at all, is a fact about cats, not about us.

According to Rescher, in this world, cats do *have to* have backbones. But that is because *we* have done some science. In another possible world, as like this world as is consistent with no one's having got around to looking at feline anatomy, cats, although just like actual cats in that they all *do* possess backbones, do not *have to*. In not having to have spines, Rescher's fictional cats would be like Popper's actual moas who, Popper tells us, did not *have to* die before the age of fifty (see Popper 1959a, pp. 427-8). But Popper, although himself like Rescher a Necessitarian, would hardly want to explain the moas' escape from necessity as having anything to do with paleontologists coming on the New Zealand scene lately and making (or failing to make as the case may be) theoretical claims about fossil remains. Popper, we may be sure, would be loath to make each moa's premature, nonnecessary demise (and each cat's not having to have a backbone) a fact about what *we* have failed to do.

There probably is no argument that is finally decisive against the extraordinarily strange consequences of Rescher's theory. And the reason is that there is probably no finally conclusive argument against Idealism itself. If one is going to identify truth with consistency, for example, or nomological necessity with 'most favored status' among consistent propositions, one *can* insulate such theories from refutation. It is much harder, however, to argue plausibly that such notions solve traditional problems. On two counts – in its view of a static science and its concomitant difficulty in explicating a timeless nomicity; and in its identification of metaphysical necessity with epistemological necessity and its concomitant implausibility in making nomological necessity an artifact of our actions – Rescher's theory seems only to aggravate the traditional problems, not solve them.

There is a third difficulty as well. And although relatively minor, it bears remarking. Rescher does not observe the twofold distinction I have insisted upon between 'real' laws and the instrumental 'laws' actually used in the day-to-day practice of science. By failing to observe this distinction, he creates still another impediment to the acceptance of his theory. For he makes truth a necessary condition of nomicity. But although truth characterizes 'real' laws, it does not characterize many of the 'laws' used by scientists. These latter propositions, as I have said (Chapter 1), are virtually all false. Thus almost none of what scientists use as laws would turn out to be nomological. But if one were to relax Rescher's necessary condition of truth, one would have the paradoxical consequence that just about every proposition that is nomologically necessary is false. Statistically, nomological necessity would be more a companion property of falsity than of truth.

I agree with Rescher that nomicity cannot be located *in re*. Where I differ is in believing that nomicity must, then, be located somewhere else. If it is true that all elm trees shed their leaves, then *this* tree sheds its leaves because it is an elm tree. We do not have to attribute nomological necessity to this just-invoked universal generalization to ground the explanatory relation. It suffices that all elm trees shed their leaves. My finger hurts because I cut it, and because cuts usually (/always) hurt. One understands this, an explanation has been given, without strengthening the generalization with a species of necessity. One need not think of cuts as 'necessarily' hurting to understand that cuts (in general) hurt and that this one (in particular) hurts.

I have concluded with this theory of necessity-through-use because I think it is important to see how much this recent attempt at rehabilitation diverges from traditional Necessitarian accounts. There is, certainly, some fundamentally correct insight in Rescher's enterprise: What gets used as laws has much to do with such matters as simplicity, fruitfulness, and degree of integration with other claims (theories, hypotheses, assumptions). Very few of the infinity of universal and statistical generalizations prove interesting or useful. Most, even those that are true, are epistemic deadwood. [Utility increases with large extension and small intension. It is much more useful to be told that all metals conduct electricity than to be told (only) that aluminum conducts electricity; although the latter is in its turn more useful than to be told that a cube of aluminum measuring 1.34 cm along each edge and having a temperature of 42° C conducts electricity.] But standing high on the scale of utility and being used as a scientific law is not the same as being nomologically necessary. Traditionally, Necessitarians have invoked nomic necessity to explain why the world not just is, but has to be, the way it is. This kind of necessity cannot – in spite of Rescher's claims – arise as an artifact (epiphenomenon?) of the way we *do* science. Elm trees lose their leaves. Either they 'merely do' (i.e., they do), or they 'have to' (i.e., they must). But *if* they must, they must because of some way the world is; not because of something you or I, or the community of botanists, do by grouping various propositions into cohesive, mutually supporting, wholes. If Necessitarianism is to be advanced, at least let it be on ontological, not epistemological, grounds. Better yet, one should approach that theory with extreme wariness.

Postscript: cosmic coincidences

At one time in the history of Western thought, it seemed mysterious that the world could 'get' from one instant of time to the next. Persistence in time was something in need of explanation. How could mere inactive matter existing *now* bring it about that matter should exist after now? The existence of matter seemed to require an active agent, and that matter-now should 'give rise' to matter-later seemed incomprehensible. Matter-now seemed no more capable of creating matter-later than matter was capable of creating itself in the first place. And thus God, a necessary being, was seen as the active creator, not just in having brought the world into being in the first instance but in re-creating (i.e., conserving, sustaining) the universe from moment to moment.

Today, few persons would be moved by such a (transcendental) argument: The Thomistic presupposition that prompts it has fallen by the wayside. It is not so much that our science has changed (although, of course, if *has* changed, enormously and profoundly), but more that our metaphysics has changed. The existence of matter is not now quite the mystery it once was. Persons today are far more prepared to allow that matter should have existed for all eternity; equally, they entertain with equanimity the hypotheses occasionally advanced by scientists that particles of matter either 'spontaneously' appear in the world or 'coalesce' out of energy. In any event, the problem of how matter manages to keep itself in existence, how it 'gets from' now to later, just simply is a dead letter today. Indeed, the very question, and its answer, have been turned about. For it is fashionable today to *define* endurance in terms of a succession of 'instantaneous time-slices': "What it *means* for an object x to endure from t_1 to t_2 is (roughly) that there should exist a series of objects very similar to x along a continuous spatial path connecting t_1 and t_2." Whether by convention, by neglect, or by fashion, or perhaps because we have grown tired of asking a question for which there seems to be no rational answer, we no longer ask what it is that brings it about that there is such a series, what it is about matter that allows matter existing at one instant to be succeeded by matter existing at a latter instant. We have reached the point where we want to say: "That's just the way the world is. Matter-now is succeeded by matter-later." We feel no need to postulate necessary creators, occult powers, or mysterious creative (or conservationist) forces in this case.

And so it should be, too, with lawfulness. There is no more nomological necessity in some sample of water having a vapor pressure of 41.8 Torr at 35° C than there is in the fact that the chipped teacup on my desk should be succeeded by a chipped teacup. The latter sequence-kind (chipped teacups-now giving rise to chipped teacups-later) is hardly a necessary feature of this world; it is just the way this world *is*. But if we have been able to dispense with the awful mystery of the endurance of teacups, then might we not – equally – be able to dispense with the invented mystery of nomicity?

On a lovely fall afternoon recently, I was driving north along Gaglardi Way approaching the intersection with the Lougheed Highway. Five red cars, of various manufacture, were lined up in a row on Lougheed stopped at the red light. When they eventually drove off, they did not seem to be traveling in a convoy (three of the five turned left), and I was quite prepared to consider the congregation of five red cars as nothing more than an eye-catching coincidence.

But although five red cars assembled in one spot might be dismissed as a mere coincidence, ten such would strain one's credulity mightily.[1] And no one would be prepared to allow that a column of cars, a thousandfold in length, all red, could be a coincidence. Large-scale coincidences cry out for explanations that reveal the contrivance, planning, or deliberation behind the phenomenon. (Of course, if *all* cars were red, there would be nothing remarkable about there being an unrelieved monotony of hue in a column of 1,000 cars. But then the reason why all cars should be red would need explaining. It was, of course, no coincidence that all early Model T Fords were black: They were black because Henry Ford ordained that they should be.)

There are probably more than 10^{60} electrons in the universe, and all of them, we may suppose, have precisely the same electrical charge. Now although I am prepared to allow that five red cars in a row might be dismissed as a coincidence, can I allow that 10^{60} items with precisely the same electrical charge is likewise a coincidence?

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[1] The improbability increase exponentially.

Modern microphysics tries to explain away this last seeming coincidence: Electrons all bear the same charge because they are constituted of subparticles *x* and *y*, and all *x*s and *y*s have properties φ and ψ, respectively. And the incipient coincidence of all *x*s and *y*s having properties φ and ψ, respectively, is explained by discovering some further subsubparticles, *u* and *v*, all having properties F' and F'', respectively. But this regress cannot go on forever; it has to stop *somewhere.* Then what do we do?

One thing we might do is swallow deeply and then say, "Well, that's just the way the world is. All these untold billions upon billions of sub- ... -subparticles all share the same properties, F_1, ... F_2; and nothing, nothing at all, accounts for this fact."

Faced with the prospect of having to say this, many persons find the sheer *contingency* of the actual world utterly fantastic: "If it wasn't God (a super Henry Ford) who designed all this and saw to it that all these countless particles are qualitatively identical, then *something* has to account for it. That 10^{60} things should all be alike in their properties cannot *rationally* be deemed 'just a coincidence.'"

Having abandoned God, the next best thing to do is to invoke a depersonalized necessity: "Ultimate particles bear identical properties because *they have to*." This claim certainly has the form of a claim that would lessen the degree of contingency.

This 'having-to' just posited cannot, of course, be a *logical* 'having-to.' (That brand of rationalism is, I take it, permanently dead.) It must then be some weaker species, some nomological necessity. But does postulating nomological necessity to explain-away what would otherwise quite literally be a cosmic coincidence really help?

At some point, we have our backs to the wall. It seems to me reasonable to think the wall to be at the point where we say, "Well, these countless particles all have the same properties because that's just the way this world is." Others prefer to think of the wall as being one step further removed: "The world is the way it is because it has to be."[2] Frankly, I just cannot convince myself that this world *has to be* this way; it just *is*.

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2 In saying this, these persons do *not* mean: "It has to be that the world is the way it is." This latter proposition is a *logical* truth.

References

Aristotle. 1963. *Categories* and *De Interpretatione*, Trans. J. L. Ackrill, Oxford University Press, London.

Bar-Hillel, Yehoshua. 1951. “A Note on State-Descriptions.” In *Philosophical Studies*, vol. 2, no. 5 (Oct.), pp. 72-5.

Barrett, William. 1958. “Determinism and Novelty.” In Hook 1958, pp. 30-9.

Beauchamp, Tom L., ed. 1974. *Philosophical Problems of Causation.* Dickenson Publishing Co., Encino, Calif.

Beauchamp, Tom L., and Alexander Rosenberg. 1981. *Hume and the Problem of Causation.* Oxford University Press, New York.

Berk, Alexander. 1983. “Complementary Variational Principle for Density-Functional Theories.” *Physical Review A [General Physics]*, 3d series, vol. 27, no. 1 (Jan.), pp. 1-11.

Bradley, Raymond D. 1967. “Must the Future Be What It Is Going to Be?” In *The Philosophy of Time*, ed. R. M. Gale, pp. 232-51. Anchor Books, Doubleday, Garden City, N.Y. Orig. pub. in *Mind*, vol. 68 (1959), pp.. 193-208.

Bradley, Raymond, and Norman Swartz. 1979. *Possible Worlds: An Introduction to Logic and its Philosophy*. Hackett Publishing, Indianapolis, and Basil Blackwell, Oxford.

Bridgman, Percy W. 1929. *The Logic of Modern Physics.* Macmillan, New York.

______ 1961. “The Present State of Operationalism.” In *The Validation of Scientific Theories,* ed. Phillip G. Frank, pp. 75-80. Collier Books, New York.

Buber, Martin. 1959. *Between Man and Man.* Trans. R. G. Smith. Beacon Press, Boston.

Buchdahl, Gerd. 1969. *Metaphysics and the Philosophy of Science.* Basil Blackwell, Oxford.

Calder, Nigel. 1979. *The Key to the Universe: A Report on the New Physics.* British Broadcasting System, London.

Carnap, Rudolf. 1953. "Testability and Meaning" (abridged). In *Readings in the Philosophy of Science*, ed. Herbert Feigl and May Brodbeck, pp. 47-92. Appleton-Century-Crofts, New York. Orig. pub. in *Philosophy of Science*, vol. 3 (1936) and vol. 4 (1937)

________ 1961. *Introduction to Semantics* and *Formalization of Logic* (orig. pub. 1942 and 1943, respectively). Harvard University Press, Cambridge, Mass.

________ 1962. *Logical Foundation of Probability* (orig. pub. 1950). 2nd ed. University of Chicago Press, Chicago.

________ 1966. *An Introduction to the Philosophy of Science.* Ed. Martin Gardner. Basic Books, Inc., New York.

Cartwright, Nancy. 1980a. "Do the Laws of Physics State the Facts?" *Pacific Philosophical Quarterly,* vol. 61, nos. 1 & 2 (Jan.-April), pp. 75-84.

________ 1980b. "The Truth Doesn't Explain Much." *American Philosophical Quarterly*, vol. 17, no. 2 (April), pp. 159-63.

Cohen, James S. 1983. "Slowing Down and Capture of Negative Muons by Hydrogen: Classical-Trajectory Monte Carlo Calculation." *Physical Review A [General Physics],* 3d series, vol. 27, no. 1 (Jan.), pp. 167-79.

Copi, Irving M. 1973. *Symbolic Logic,* 4th ed. Macmillan, New York.

Cornell, James. 1976. *The Great International Disaster Book,* Scribner, New York.

Dretske, Fred. 1977. "Laws of Nature." In *Philosophy of Science,* vol. 44, no. 2 (June), pp. 248-68.

Ducasse, Curt John. 1966. "Critique of Hume's Conception of Causality." *Journal of Philosophy,* vol. 63, no. 6 (March 17), pp. 141-8. Reprinted in Beauchamp 1974, pp. 6-11.

________ 1969. *Causation and the Types of Necessity* (orig. pub. 1924). Dover Publications, New York.

Faris, J. A. 1964. *Quantification Theory.* Routledge & Kegan Paul, London. Gasser, F., and C. Tavard. 1983. "Atomic K- and L-shell Compton Defects for the Study of Electronic Structures." *Physical Review A [General Physics],* 3d series, vol. 27, no. 1 (Jan.), pp. 117-23.

Giere, Ronald N. 1977. "Testing Versus Informational Models of Statistical Inference." In *Logic, Laws, and Life*, ed. R. G. Colodny, vol. 6, pp. 19-70. University of Pittsburgh Press, Pittsburgh, University of Pittsburgh Series in the Philosophy of Science.

Goodman, Nelson. 1965. *Fact, Fiction and Forecast.* Bobbs-Merrill, Indianapolis.

Hanson, Norwood Russell. 1967. "Philosophical Implications of Quantum Mechanics." In *Encyclopedia of Philosophy,* vol. 7, pp. 41-9. Macmillan and Free Press, New York.

Hempel, Carl G. 1949. "The Function of General Laws in History." In *Readings in Philosophical Analysis*, ed. H. Feigl and W. Sellars, pp. 459-71. Appleton-Century-Crofts, New York. Orig. pub. in *Journal of Philosophy,* vol. 39 (1942).

________ 1965. "Studies in the Logic of Confirmation." Reprinted with some changes and "Postscript (1964)" in *Aspects of Scientific Explanation*, pp. 3-51. Free Press, New York. Orig. pub. in *Mind*, vol. 54 (1945) pp. 1-26, 97-121.

Honderich, Ted. 1979. "One Determinism." Revised with added introduction in *Philosophy As It Is*, ed. Ted Honderich and Myles Burneat, pp. 239-75. Penguin Books, New York. Orig. pub. in *Essays on Freedom of Action*, ed. Ted Honderich, Routledge & Kegan Paul, London, 1973.

Hook, Sidney, ed. 1958. *Determinism and Freedom in the Age of Modern Science.* New York University Press, New York.

Hume, David. 1955 *An Inquiry Concerning Human Understanding* (orig. pub. 1748). Bobbs-Merrill Company, Indianapolis.

Huntington, H. B., and R. K. MacCrone. 1983. "Hysteresis." In *McGraw-Hill Encyclopedia of Physics*, p. 452. McGraw-Hill Book Company, New York.

Kahneman, Daniel, and A. Tversky. 1982. "The Simulation Heuristic." In *Judgment Under Uncertainty: Heuristics and Biases*, ed. D. Kahneman, P. Slovic, and A. Tversky, pp. 201-8. Cambridge University Press, New York.

Kemeny, John G., 1959. *A Philosopher Looks at Science.* Van Nostrand, Princeton, N.J.

Keynes, John Maynard. 1963. *A Treatise on Probability* (orig. pub. 1921; 2nd ed. 1929). Macmillan, London.

Kneale, William. 1950. "Natural Laws and Contrary-to-Fact Conditionals." *Analysis,* vol. 10, no. 6 (June), pp. 121-5. Reprinted in Beauchamp 1974, pp. 46-9

________ 1961. "Universality and Necessity." *British Journal for the Philosophy of Science,* vol. 12, no. 46 (August), pp. 89-102. Reprinted in Beauchamp 1974, pp. 53-63.

Kuhn, Thomas S. 1970. *The Structure of Scientific Revolutions.* 2nd ed., enlarged. University of Chicago Press, Chicago.

Kyburg, Henry E., Jr. 1970. *Probability and Inductive Logic.* Macmillan Company, London.

Laplace, Pierre Simon. 1951. *A Philosophical Essay on Probabilities.* Trans. F. W. Truscott and F. L. Emory. Dover Publications, New York.

Lewis, David. 1973. *Counterfactuals.* Harvard University Press, Cambridge, Mass.

Lewis, H. D. 1952. "Guilt and Freedom." Reprinted (with minor changes) in *Readings in Ethical Theory* (1st ed. only), ed. Wilfred Sellars and John Hospers, pp. 587-620. Appleton-Century-Crofts, New York. Orig. pub. in *Proceedings of the Aristotelian Society,* supplementary vol. 21 (1947). Reprinted in *Morals and Revelation,* Allen & Unwin, London, 1951.

Lin, C. D. 1983. “Radial and Angular Correlations of Two Excited Electrons. III. Comparison of Configuration-Interaction Wave Functions with Adiabatic Channel Functions in Hyperspherical Coordinates.” *Physical Review A [General Physics],* 3rd series, vol. 27, no. 1 (Jan.), pp. 22-8.

Mabbott, J. D. 1961. “Freewill and Punishment.” In *Contemporary British Philosophy, Third Series,* ed. H. D. Lewis, pp. 289-309. 2nd ed. Allen & Unwin, London.

Mackie, J. L. 1974. *The Cement of the Universe: A Study of Causation.* Oxford University Press, London.

McKinnon, Alastair. 1967. “ ‘Miracle’ and ‘Paradox.’ ” *American Philosophical Quarterly,* vol. 4, pp. 308-14.

McNutt, Joe F., and C. William McCurdy. 1983. “Complex Self-Consistent Field and Configuration-Interaction Studies of the Lowest ^2P Resonance State of Be^-.” *Physical Review A [General Physics],* 3rd series, vol. 27, no. 1 (Jan.), pp. 132-40.

Madden, Edward H. 1969. “A Third View of Causality.” *Review of Metaphysics,* vol. 23, no. 1 (Sept.), pp. 67-84. Reprinted in Beauchamp 1974, pp. 178-89.

Marx, Karl. 1963. *The Eighteenth Brumaire of Louis Bonaparte* (orig. pub. 1852; 2nd ed. 1869; 3rd ed. 1885). International Publishers, New York.

Maxwell, Nicholas. 1968. “Can There Be Necessary Connections between Successive Events?” *British Journal for the Philosophy of Science,* vol. 19, pp. 1-25.

Mill, John Stuart. 1965. *A System of Logic: Ratiocinative and Inductive* (8th ed., 1881). Longmans, Green, London.

Millikan, Roger C. 1983. “The Magic of the Monte Carlo Method.” *Byte,* vol. 8 (Feb.), pp. 371-3.

Mills, Allen P., Jr. 1983. “Line-Shape Effects in the Measurement of the Positronium Hyperfine Interval.” *Physical Review A [General Physics],* 3rd series, vol. 27, no. 1 (Jan.), pp. 262-7.

Mises, Richard von. 1961. *Probability, Statistics and Truth.* 2nd rev. English ed. Allen & Unwin, London.

Molnar, George. 1969. “Kneale’s Argument Revisited.” *Philosophical Review,* vol. 78, no. 1 (Jan.), pp. 79-89. Reprinted in Beauchamp 1974, pp. 106-13.

Nagel, Ernest. 1961. *The Structure of Science.* Harcourt, Brace & World, New York.

Nerlich, G. C., and W. A. Suchting. 1967. “Popper on Law and Natural Necessity.” *British Journal for the Philosophy of Science,* vol. 18, pp. 233-5. Reprinted in Beauchamp 1974, pp. 63-5.

Pagels, Heinz R. 1983. *The Cosmic Code: Quantum Physics as the Language of Nature.* Bantam Books, New York.

Pap, Arthur. 1962. *An Introduction to the Philosophy of Science.* Free Press of Glencoe (Macmillan), New York.

Pears, D. F., ed. 1966. *Freedom and the Will.* Macmillan, London.

Pearson, Karl. 1960. *The Grammar of Science* (orig. pub. 1892, rev. 1900, 1911). Meridian Books, New York.

Peirce, C. S. 1892. “The Doctrine of Necessity Examined.” *The Monist,* vol. 2, pp. 321-38. Reprinted in *Collected Papers of Charles Saunders Peirce,* ed. C. Hartshorne and P. Weiss, vol. 6, pp. 28-45. Harvard University Press, Cambridge, Mass., 1931-5. And reprinted in *Essays in the Philosophy of Science,* ed. Vincent Thomas, pp. 170-88. Bobbs-Merrill, Indianapolis, 1957.

Penelhum, Terence. 1967. “Personal Identity.” In *Encyclopedia of Philosophy,* vol. 6, pp. 95-107. Macmillan and Free Press, New York.

Popper, Karl. 1959a. *The Logic of Scientific Discovery.* Basic Books, New York.

________ 1959b. “The Propensity Interpretation of Probability.” In *British Journal for the Philosophy of Science,* vol. 10, pp. 25-42.

________ 1962a. *Conjectures and Refutations.* Basic Books, New York.

________ 1962b. “The Propensity Interpretation of the Calculus of Probability, and the Quantum Theory.” In *Observation and Interpretation in the Philosophy of Physics* (orig. pub. 1957), ed. Stephen Korner, pp. 65-70. Dover Publications, New York.

________ 1974. “Suppes’s Criticism of the Propensity Interpretation of Probability and Quantum Mechanics.” In *The Philosophy of Karl Popper,* ed. Paul Arthur Schilpp, pp. 1125-40. Open Court, La Salle, IL.

Prior, A. N. 1967. “Correspondence Theory of Truth.” In *Encyclopedia of Philosophy,* vol. 2, pp. 223-32. Macmillan and Free Press, New York.

Putnam, Hilary. 1975. “The Meaning of ‘Meaning’.” In *Mind, Language and Reality, Philosophy Papers,* vol. 2, pp. 215-71. Cambridge University Press, Cambridge. Orig. pub. in *Language, Mind and Knowledge,* Minnesota Studies in the Philosophy of Science, vol. 7, ed. K. Gunderson, pp. 131-93. University of Minnesota Press, Minneapolis, 1975.

Quinton, Anthony. 1973. *The Nature of Things.* Routledge & Kegan Paul, London.

Reichenbach, Hans. 1954. *Nomological Statements and Admissible Operations.* North-Holland Publishing Co., Amsterdam.

Rescher, Nicholas. 1970. *Scientific Explanation,* Free Press, New York.

Ryle, Gilbert. 1960. “It Was to Be.” In *Dilemmas* (orig. pub. 1954), pp. 15-35. Cambridge University Press, Cambridge.

Russell, Bertrand. 1938. *The Principles of Mathematics* (orig. pub. 1903). 2nd. ed. Norton, New York.

________ 1956. "The Philosophy of Logical Atomism" (orig. pub. 1918). Reprinted in *Logic and Knowledge: Essays1901-1950*, ed. Robert C. Marsh, pp. 177-281. Allen & Unwin, London.

________ 1965. "On the Notion of Cause." In *On the Philosophy of Science*, ed. C. A. Fritz Jr., pp. 163-86. Bobbs-Merrill Company, Indianapolis. Orig. pub. in *Proceedings of the Aristotelian Society*, vol. 13 (1912-13); and subsequently in *Mysticism and Logic* (1st ed., 1918; 2nd ed., 1929), ch. 9, pp. 180-208. Allen & Unwin, London.

Scheffler, Israel. 1966. "Inductive Inference: A New Approach." In *Probability, Confirmation, and Simplicity*, ed. M. H. Foster and M. L. Martin, pp. 450-9 Odyssey Press, New York. Orig. pub. in *Science*, vol. 127, no. 3291 (Jan. 24, 1958), pp. 177-81.

________ 1967. *Science and Subjectivity.* Bobbs-Merrill, Indianapolis.

Schlegel, Richard. 1967. *Completeness in Science.* Appleton-Century-Crofts, New York.

Schrödinger, Erwin. 1983. "Die gegenwärtige Situation in der Quantenmechanik." In Wheeler and Zurek 1983, pp. 152-67. Orig. pub. in *Naturwissenschaften*, vol. 23 (1935), pp. 807-12, 823-8, 844-9. Trans. as "The Present Situation in Quantum Mechanics" by J. D. Trimmer. *Proceedings of the American Philosophical Society*, vol. 124 (1980), pp. 323-38. Latter version reprinted in Wheeler and Zurek 1983.

Scriven, Michael. 1961. "The Key Property of Physical Laws – Inaccuracy." In *Current Issues in the Philosophy of Science – Proceedings of Section L of the American Association for the Advancement of Sciences, 1959*, ed. H. Feigl and G. Maxwell, pp. 91-104. Holt, Rinehart and Winston, New York.

________ 1965. "An Essential Unpredictability in Human Behavior." In *Scientific Psychology: Principles and Approaches*, ed. Ernest Nagel and Benjamin Wolman, pp. 411-25. Basic Books, New York.

Shoemaker, Sidney. 1969. "Time Without Change." *Journal of Philosophy*, vol. 66, no. 12 (June 19), pp. 363-81.

Sobel, Max A., and Evan M. Maletsky. 1974. *Mathematics II.* Ginn and Co., Division of Xerox of Canada, Scarborough, Ontario.

Sosa, Ernest, ed. 1975. *Causation and Conditionals*, Oxford University Press, Oxford.

Stern, Chaim, ed. 1978. *Gates of Repentance – The New Union Prayerbook for the Days of Awe.* Central Conference of American Rabbis, New *York.*

Strawson, Peter. 1964. *Individuals: An Essay in Descriptive Metaphysics* (orig. pub. 1959). Methuen, London.

Swartz, Norman. 1973. “Is There an Ozma-Problem for Time?” *Analysis,* vol. 33, no. 3, new series no. 153 (Jan.), pp. 77-82.

________ 1975. “Spatial and Temporal Worlds: Could There Be More than One of Each?” *Ratio,* vol. 17, no. 2 (Dec.), pp. 217-28.

Swinburn, Richard. 1970. *The Concept of Miracle,* Macmillan, London.

Taylor, Richard. 1964. “Spatial and Temporal Analogies and the Concept of Identity.” Orig. pub. in *Journal of Philosophy,* vol. 52 (1955). In *Problems of Space and Time,* ed. J. J. C. Smart, pp. 381-96. Macmillan Company, New York.

________ 1983. *Metaphysics.* 3rd ed. Esp. chs. 5, 6, 9. Prentice-Hall, Englewood Cliffs, N.J.

Todd, William. 1964. “Counterfactual Conditionals and the Presuppositions of Induction.” *Philosophy of Science,* vol. 31, no. 2 (April), pp. 101-110.

Waismann, Friedrich. 1965. *The Principles of Linguistic Philosophy,* ed. R. Harre. Macmillan, London.

Walker, Marshall. 1963. *The Nature of Scientific Thought.* Prentice-Hall, Englewood Cliffs, N.J.

Wheeler, John A., and W. J. Zurek, eds. 1983. *Quantum Theory and Measurement.* Princeton University Press, Princeton, N.J.

Wigner, Eugene P. 1967. “Remarks on the Mind-Body Problem.” Ch. 13 in *Symmetries and Reflections*, pp. 171-84. Indiana University Press, Bloomington. Reprinted in Wheeler and Zurek 1983, pp. 168-81.

Williams, Clifford. 1980. *Free Will and Determinism: A Dialogue.* Hackett Publishing, Indianapolis.

Wittgenstein, Ludwig. 1961. *Tractatus Logico-Philosophicus.* Trans. D. F. Pears and B. F. McGuinness. Routledge & Kegan Paul, London. Orig. pub. as *Logisch philosophische Abhandlung,* 1921.

Wollheim, Richard. 1967. “Natural Laws.” In *Encyclopedia of Philosophy,* vol. 5, pp. 450-4 Macmillan and Free Press, New York.

Wright, Georg Henrik von. 1974. *Causality and Determinism.* Columbia University Press, New York.

Wright, John P. 1983. *The Sceptical Realism of David Hume.* Manchester University Press, Manchester.

Index

Examples, test cases, and case studies are gathered under the entry "case studies."

Linguistic items, other than sentences, for example, "indexicals" and "variables," are to be found under the entry "terms."

Symbols may be found under the entry "symbols".