

Disposition Concepts and Extensional Logic

One of the striking differences between natural languages, both conversational and scientific, and the extensional languages constructed by logicians is that most conditional statements, i.e., statements of the form “if p , then q ”, of a natural language are not truth-functional. A statement compounded out of simpler statements is truth-functional if its truth-value is uniquely determined by the truth-values of the component statements. The symbolic expression of this idea of truth-functionality, as given in *Principia Mathematica*, is $p \equiv q \supset (f(p) \equiv f(q))$. That is, if “ $f(p)$ ” is any truth-function of “ p ”, and “ q ” has the same truth-value as “ p ”, however widely it may differ in meaning, then “ $f(q)$ ” has the same truth-value as “ $f(p)$ ”. Clearly, if I am given just the truth-values of “ p ” and “ q ”, not their meanings, I cannot deduce the truth-value of “if p , then q ”—with a single exception: if “ p ” is given as true and “ q ” as false, it follows that “if p , then q ” is false, provided it has a truth-value at all. On the contrary, the knowledge that matters for determination of the truth-value of a “natural” conditional—let us call them henceforth “natural implications”, in contrast to those truth-functional statements which logicians call “material conditionals” or “material implications”—is rather knowledge of the meanings of the component statements. In the case of simple analytic implications like “if A has a niece, then A is not an only child” such knowledge of meanings is even sufficient for knowledge of the truth of the implication; at any rate knowledge of the truth-value of antecedent and consequent is irrelevant. In the case of those synthetic natural implications which assert causal connections, knowledge of meanings is not, indeed, sufficient, but it is necessary, and knowledge of the truth-values of the component statements is not presupposed by knowledge of the truth-value of the implication.¹ Consider the conditional (which may or may

not be “contrary-to-fact”): if I pull the trigger, the gun will fire. It would be sad if belief in such an implication were warranted only by knowledge of the truth of antecedent and consequent separately, for in that case it would be impossible for man to acquire the power of even limited control over the course of events by acquiring warranted beliefs about causal connections. Notice further that frequently presumed knowledge of a causal implication is a means to knowledge of the truth, or at least probability, of the antecedent; if this is an acid then it will turn blue litmus paper red; the reaction occurred; thus the hypothesis is confirmed. Knowledge of the consequences of suppositions is independent of knowledge of the truth-values of the suppositions, no matter whether the consequences be logical or causal.

The difference between material implication and natural implication has been widely discussed. The logician’s use of “if p , then q ” in the truth-functional sense of “not both p and not- q ”, symbolized by “ $p \supset q$ ”, is fully justified by the objective of constructing an adequate theory of deductive inference, since the intensional meaning of “if, then”, be it logical or causal connection, is actually irrelevant to the validity of formal deductive inferences involving conditional statements. This is to say that such conditional inference-forms as *modus ponens*, *modus tollens*, and hypothetical syllogism would remain valid in the sense of leading always to true conclusions from true premises if their conditional premises or conditional conclusions were interpreted as material conditionals asserting no “connections” whatever. The so-called, and perhaps misnamed, paradoxes of material implication, viz., that a false statement materially implies any statement and a true statement is materially implied by any statement, are not logical paradoxes. The formal logician need not be disturbed by the fact that the statements “if New York is a small village, then there are sea serpents” and “if New York is a small village, then there are no sea serpents” are, as symbolized in extensional logic, both true; for since this is due to the falsity of their common antecedent, *modus ponens* cannot be applied to deduce the contradiction that there both are and are not sea serpents. No contradiction arises. However, it is in the application of extensional logic for the purpose of precise formulation of empirical concepts and propositions that serious difficulties arise. The “paradoxical” feature of material implication that the mere falsehood of the antecedent ensures the truth of the implication leads, not to formal inconsistency, but to

grossly counterintuitive factual assertions when extensional logic is applied to the language of empirical science. This becomes particularly evident if one tries to formalize so-called *operational definitions* by means of extensional logic. For the definiens of an operational definition is a conditional whose antecedent describes a test operation and whose consequent describes a result which such an operation has if performed upon a certain kind of object under specified conditions. A concept which is operationally defined in this sense may be called a “disposition concept.” Suppose, then, that a disposition concept is defined by a material conditional as follows:

$$Dx,t = (Ox,t \supset Rx,t) \dots \quad (D_1)$$

The question might be raised whether the time-argument could be omitted from the disposition predicate, so that the definition would look as follows: $Dx = (t)(Ox,t \supset Rx,t)$. Which form of definition is suitable depends on inductive considerations. If the disposition is “intrinsic” in the sense that a generalization of the form $(t)(x)[x \in K \supset (Ox,t \supset Rx,t)]$ has been highly confirmed (where K is a natural kind), a time-independent disposition predicate is appropriate. Examples of such intrinsic dispositions are solubility and melting point (the latter is an example of a quantitative disposition whose operational definition accordingly would require the use of functors, not just of qualitative predicates). On the other hand, the symbol “ Dx,t ” is appropriate if D is such that for some objects y both “ $(\exists t)(Oy,t \cdot Ry,t)$ ” and “ $(\exists t)(Oy,t \cdot \sim Ry,t)$ ” holds; for example, being electrically charged, elasticity, irritability. Now, as Carnap pointed out in *Testability and Meaning*, a definition of the form of D_1 has the counterintuitive consequence that any object has D at any time at which it is not subjected to O , and that any object on which O is never performed has D at all times.²

There is a close analogy between the interpretation of the Aristotelian A and E propositions as generalized material implications (or “formal implications,” in Russell’s terminology) and the extensional interpretation of operational definitions, in that both have the consequences that intuitively incompatible statements are compatible after all. If “all A are B ” means “ $(x)(Ax \supset Bx)$ ” and “no A are B ” means “ $(x)(Ax \supset \sim Bx)$ ”, then both may be true, since both would be true if nothing had the property A , which is logically possible. Thus the student introduced to extensional symbolic logic learns to his amazement that both

“all unicorns live in the Bronx zoo” and “no unicorns live in the Bronx zoo” are true statements—for the simple reason that there are no unicorns, from which it follows that there are no unicorns of any kind, neither unicorns that live in the Bronx zoo nor unicorns that don’t live in the Bronx zoo. Similarly, suppose a physical functor like “temperature” were operationally defined as follows: $\text{temp}(x,t) = y =_{\text{def}} a$, a thermometer is brought into thermal contact with x at $t \supset$ the top of the thermometric liquid coincides with the mark y at $t + dt$. Then the clearly incompatible statements “ $\text{temp}(a,t_0) = 50$ ” and “ $\text{temp}(a,t_0) = 70$ ” would both be true, on the basis of this definition, if no thermometer were in contact with a at t_0 ; indeed a would have all temperatures whatsoever at any time at which its temperature is not measured.³

Some philosophers have suggested that the reason why counterintuitive consequences result if material implication is substituted for natural implication is that a material implication is true in cases where the corresponding natural implication has no truth-value. If the antecedent of a natural implication is false, they suggest, then the natural implication is “undetermined”; it is true just in case both antecedent and consequent are true, and false in case the antecedent is true and the consequent is false.⁴ Now, the combinations FF and FT do, indeed, leave the truth-value of a natural implication undetermined in the sense that they leave it an open question which its truth-value is. But the same holds for the combination TT . It is not the case that every true statement naturally implies every true statement. If it should be replied that nevertheless the joint truth of antecedent and consequent *confirms* a natural implication, it must be pointed out that if so, then the joint falsehood of antecedent and consequent likewise confirms it, by the principle that whatever evidence confirms a given statement S also confirms whatever statement is logically equivalent to S :⁵ if “ p and q ” confirms “if p , then q ”, then “not- q and not- p ” confirms “if not- q , then not- p ”, and therefore confirms “if p , then q ”. Or, to put it differently but equivalently: if “ p and q ” confirms “if p , then q ” then it also confirms “if not- q , then not- p ”, but this is to say that a natural implication is confirmable by an FF case. To illustrate: suppose I say to a student “if you study for the course at least one hour every day, then you will pass the course.” If this conditional prediction is confirmed by the fact that the advised student put in at least one hour for the course every day and passed the course, then the same fact ought to confirm the

equivalent prediction formulated in the future perfect: "if you will not pass the course, then you will not have studied for it at least one hour every day." But further, it just is not the case that no truth-value is ordinarily assigned to a natural implication whose antecedent is false. Everybody distinguishes between true and false *contrary-to-fact* conditionals. In particular, the belief that an object has a certain disposition may motivate people to subject it, or prevent it from being subjected, to the corresponding test operation; we are, for example, careful not to drop a fragile and valuable object because we believe that it would break if it were dropped. What we believe is a proposition, something that is true or false; to say that it only *becomes* true when its antecedent and consequent are confirmed, is to confuse truth and confirmation.⁶

Let us see, now, whether perhaps a more complicated kind of explicit definition of disposition concepts within the framework of extensional logic can be constructed which avoids the shortcoming of D_1 : that an object upon which test operation O is not performed has any disposition whatsoever that is defined by means of O . Philosophers who follow the precept "to discover the meaning of a factual sentence 'p' reflect on the empirical evidence which would induce you to assert that p" might arrive at such a definition by the following reasoning. What makes one say of a wooden object that it is not soluble in water even before testing it for solubility in water, i.e., before immersing it in water? Obviously its similarity to other objects which have been immersed in water and were found not to dissolve therein. And what makes one say of a piece of sugar that it is soluble before having immersed it? Evidently the fact that other pieces of sugar have been immersed and found to dissolve. In general terms: the evidence " $(x_1 \in K \cdot O x_1 \cdot R x_1) \cdot (x_2 \in K \cdot O x_2 \cdot R x_2) \dots (x_n \in K \cdot O x_n \cdot R x_n)$ " led to the generalization " $(x)(x \in K \supset (O x \supset R x))$ " from which, together with " $x_0 \in K$ ", we deduce " $O x_0 \supset R x_0$ ". The latter conditional is not *vacuously* asserted, i.e., just on the evidence " $\sim O x_0$ ", but it is asserted on the specified *inductive* evidence. Such *indirect confirmability*⁷ of dispositional statements seems accurately reflected by the definition schema:⁸

$$Dx = (\exists f)[fx \cdot (\exists y)(\exists t)(fy \cdot O y, t) \cdot (z)(t)(fz \cdot O z, t \supset R z, t)] \quad (D_2)$$

If we take as values of "f" alternatively "being wooden" and "being sugar", then it can easily be seen that on the basis of such a definition, involving application of the higher functional calculus to descriptive

predicates, wooden objects that are never immersed in a liquid L are not soluble in L, whereas pieces of sugar can with inductive warrant be characterized as soluble in L even if they are not actually immersed in L.

Unfortunately, however, the undesirable consequences of D_1 reappear if certain artificial predicates are constructed and substituted for the predicate variable "f". Thus Carnap pointed out to Kaila that if " $(x = a) \vee (x = b)$ ", where a is the match that was burned up before ever making contact with water and b an object that was immersed and dissolved, is taken as the value of "f", "Da" is again provable. This seemed to be a trivial objection, since evidently "f" was meant to range over "properties" in the ordinary sense of "property": who would ever say that it is a property of the match to be either identical with itself or with the lump of sugar on the saucer? But if "f" is restricted to *general* properties, i.e., properties that are not defined in terms of individual constants, the undesirable consequences are still not precluded. As Wedberg pointed out (*loc. cit.*), vacuous confirmation of dispositional statements would still be possible by taking " $O \supset R$ " as value of "f". Nevertheless, I doubt whether the objection from the range of the predicate variable is insurmountable. To be sure, it would lead us to a dead end if we defined the range of "f" as the class of properties that determine *natural kinds*. For our philosophical objective is to clarify the meaning of "disposition" by showing how disposition concepts are definable in terms of clearer concepts. But I suspect that we need the concept of "disposition" for the explication of "natural kind", in the following way: if a class K is an ultimate natural kind (an *infima species*, in scholastic terminology), then, if one member of K has a disposition D, all members of K have D. If "ultimate natural kind" could be satisfactorily defined along this line, "natural kind" would be simply definable as "logical sum of ultimate natural kinds". To illustrate: would a physicist admit that two samples of iron might have a different melting point? He would surely suspect impurities if the two samples, heated under the same standard pressure, melted at different temperatures. And after making sure that the surprising result is not due to experimental error, he would invent names for two subspecies of iron—that is, he would cease to regard iron as an "ultimate" kind—and look for differentiating properties other than the difference of melting point in order to "account" for the latter.

But be this as it may, it seems that vacuous truth of dispositional

statements could be precluded without dragging in the problematic concept of "natural kind" by the following restriction on the range of "f": we exclude not only properties defined by individual constants, but also general properties that are truth-functional compounds of the observable transient properties O and R.⁹ There remains, nevertheless, a serious objection relating to the second conjunct in the scope of the existential quantifier: there is a confusion between the meaning of a dispositional statement and the inductive evidence for it. To see this, just suppose a universe in which the range of temperature is either so high or so low that liquids are causally impossible in it. If so, nothing can ever be immersed in a liquid, hence, if "Oy,t" means "y is immersed in L at t", " $(\exists y)(\exists t)(fy \cdot Oy,t)$ " will be false for all values of "f". But surely the meaning of "soluble" is such that even relative to this imaginary universe "sugar is soluble" would be true: in using the dispositional predicate "soluble" we express in a condensed way the subjunctive conditional "if a sample of sugar were immersed in a liquid, then it would dissolve," and this just does not entail that some sample of sugar, or even anything at all, is ever *actually* immersed in a liquid. True, no mind could have any evidence for believing a proposition of the form "x is soluble" if nothing were ever observed to dissolve; indeed, it is unlikely that a conscious organism living in our imaginary universe (for the sake of argument, let us assume that the causal laws governing that universe are such that conscious life is possible in it in spite of the prevailing extreme temperatures) would even have the concept of solubility. But it does not follow that the proposition could not be true just the same.

The idea underlying D_2 is obviously this: the evidence on which a contrary-to-fact conditional is asserted—if it is a confirmable, and hence cognitively meaningful, statement at all—is some law that has been confirmed to some degree; therefore the conditional is best analyzed as an implicit assertion of the existence and prior confirmation of a law connecting O and R.¹⁰ Now, I agree that the existence of some law in accordance with which the consequent is deducible from the antecedent is implicitly asserted by any singular counterfactual conditional, though the assertor may not be able to say *which* that law is (formally speaking, he may not know which value of "f" yields a universal conditional—the third conjunct of the definiens—which is probably true). To take an extreme example: if I say, "if you had asked your landlord

more politely to repaint the kitchen, he would have agreed to do it," I have but the vaguest idea of the complex psychological conditions that must be fulfilled if a landlord is to respond favorably to a tenant's request which he is not legally obligated to satisfy, yet to the extent that I believe in determinism I believe that *there is* a complex condition which is causally sufficient for a landlord's compliance with such a request.¹¹ But that there is confirming evidence for the law whose existence is asserted—and more specifically *instantial* evidence—is *causally*, not *logically*, presupposed by the assertion of the dispositional statement. A proposition q is causally presupposed by an assertion of proposition p, if p would not have been asserted unless q had been believed; in other words, if the acceptance of q is one of the causal conditions for the assertion of p;¹² whereas q is logically presupposed by the assertion of p, if p entails q. To add an illustration to the one already given: consider the singular dispositional statement "the melting point of x is 200° F", which means that x would melt at any time at which its temperature were raised to 200° F (provided the atmospheric pressure is standard). Surely this proposition is logically compatible with the proposition that nothing ever reaches the specified temperature. That there should be instantial evidence for a law of the form "any instance of natural kind K would, under standard atmospheric pressure, melt if it reached 200° F" is therefore not logically presupposed by the dispositional statement, though very likely it is causally presupposed by its assertion.

Could our schema of explicit definition, then, be salvaged by extruding the existential clause? Only if " $(z)(Fz \cdot Oz \supset Rz)$ " (where "F" is a constant predicate substituted for the variable "f") were an adequate expression of a law. But that it is not follows from the fact that it is entailed by " $\sim(\exists z)(Fz \cdot Oz)$." Thus, if "F" means "is wooden", and it so happens that no wooden thing is ever immersed in a liquid, it would be true to say of a match that it is soluble. It may well be that to ascribe D to x is to ascribe to x some intrinsic property f (however "intrinsic" may be explicated) such that "Rx" is deducible from "fx · Ox" by means of a law; but this, as most writers on the contrary-to-fact conditional have recognized, leaves the extensionalist with the tough task of expressing laws in an extensional language. The view that every *singular* counterfactual conditional derives its warrant from a *universal* conditional is sound—though one cannot tell by a mere glance

at the predicates of the singular conditional which universal conditional is presupposed¹³—but it should not be overlooked that universal conditionals that are accorded the status of laws by scientists may themselves be counterfactual. There are no finite physical systems that are strictly closed, isolated from external influences, but the law of the conservation of energy says that if there were such a system its total energy would remain constant; there are no gases that are “ideal” in the sense that their molecules do not exert “intermolecular” forces on one another, but the general gas law says that if there were such a gas it would exactly satisfy the equation “ $PV = RT$ ”; there are no bodies that are not acted on by any external forces (indeed, the existence of such bodies is incompatible with the universal presence of gravitation), but the law of inertia says that if there were such a body it would be in a state of rest or uniform motion relative to the fixed stars.¹⁴ If such laws were formulated extensionally, as negative existential statements, like “there are no ideal gases that do not satisfy the equation: $PV = RT$ ”, they would be vacuously true; anything whatsoever could be truly asserted to happen under the imagined unrealizable conditions. And it could hardly be maintained that, in analogy to the process of validation of singular contrary-to-fact conditionals, such laws are asserted as consequences of more general laws that have been instantially confirmed. If the general gas law, for example, is asserted as a deductive consequence of anything, then it is of the kinetic theory of gases, whose constituent propositions are surely not the kind of generalizations that could be instantially confirmed.¹⁵

But further, there is the much-discussed difficulty of distinguishing extensionally laws from universal propositions that are but *accidental*. It may be the case that all the people who ever inhabited a certain house H before H was torn down died before the age of 65. The statement “for any x, if x is an inhabitant of H, then x dies before 65” would then be true, yet nobody would want to say that it expresses a law. As Chisholm and Goodman have pointed out, if it were a law, then it would support a counterfactual conditional like “if Mr. Smith (who is not one of the inhabitants of H) had inhabited H, he would have died before 65.” Now, an extensionalist might try the following approach: what distinguishes laws from accidental universals is, not an obscure modality of existential necessity (as contrasted with logical necessity), but their strict universality. That is, a universal statement

expresses a law only if either it contains no individual constants or else is deducible as a special case from well-confirmed universal statements that contain no individual constants. The predicates of the fundamental laws, i.e., those that contain no individual constants, should be purely general.

However, a serious criticism must be raised against this approach. Just suppose that H were uniquely characterized by a property P which is purely general in the sense that it *might* be possessed by an unlimited number of objects.¹⁶ P might be the property of having a green roof; that is, it might happen that H and only H has P. In that case the accidental universal could be expressed in terms of purely general predicates: for any x, if x is an inhabitant of a house that has a green roof, then x dies before 65.¹⁷ It may be replied that although the antecedent predicate is purely general it refers, in the above statement, to a finite class that can be exhausted by enumeration of its members, and that it is this feature which marks the statement as accidental. Admittedly, so the reply may continue, it sounds absurd to infer from it “if y were an inhabitant of a house that has a green roof, then y would die before 65,” but this is because we tacitly give an intensional interpretation to the antecedent predicate. If instead it were interpreted extensionally, viz., in the sense of “if y were identical with one of the elements of the actual extension of the predicate,” the inferred subjunctive conditional would be perfectly reasonable. To cite directly the proponent of this explication of the distinction under discussion, Karl Popper: “. . . the phrase ‘If x were an A . . .’ can be interpreted (1) if ‘A’ is a term in a strictly universal law, to mean ‘If x has the property A . . .’ (but it can also be interpreted in the way described under (2)); and (2), if ‘A’ is a term in an ‘accidental’ or numerically universal statement, it must be interpreted ‘If x is identical with one of the elements of A.’”¹⁸

But this just won’t do. For “x is one of the elements of A” would, in the sense intended by Popper, be expressed in the symbolism of *Principia Mathematica* as follows: $x = a \vee x = b \vee \dots \vee x = n$, where $a, b \dots n$ are all the actual members of A.¹⁹ But if Popper were right, then, if “all A are B” is accidental, it could be analytically deduced from it that such and such objects are members of B, which is surely not the case. To prove this formally for the case where the actual extension of “A” consists of just two individuals a and b: $(x)(x = a \vee x = b \supset x \in B)$

is equivalent to $(x)[(x = a \supset x \in B) \cdot (x = b \supset x \in B)]$, which is equivalent to the simple conjunction: $a \in B \cdot b \in B$. But surely it can be supposed without self-contradiction that, as a matter of accident, all the inhabitants of houses with green roofs die before 65, and yet individual a , or individual b , survives the age of 65. What is logically excluded by the accidental universal is only the *conjunctive* supposition that a is an inhabitant of a house with a green roof and survives the age of 65. It is not denied that " $a \in B \cdot b \in B$," where a and b happen to be the only objects that have property A , is the *ground*, indeed the *conclusive ground*, on which the accidental universal "all A are B " is asserted; what is denied is that any *atomic* statements, or conjunctions of such, are analytically entailed by a universal statement, regardless of whether it is accidental or lawlike. The same confusion of the meaning of the universal statement with the ground on which it is asserted is involved in the following interpretation: $(a \in A) \cdot (a \in B) \cdot (b \in A) \cdot (b \in B) \dots (n \in A) \cdot (n \in B) \cdot (x)(x \in A \equiv x = a \vee x = b \vee \dots \vee x = n)$. For clearly none of the atomic statements are entailed by the universal statement "all A are B ."

But suppose that accidental universals were characterized pragmatically rather than semantically, in terms of the nature of the evidence which makes them warrantably assertable. Thus P. F. Strawson²⁰ suggests that only the knowledge that all the members of A have been observed and found to be B constitutes a good reason for asserting an accidental universal "all A are B ." Now, Strawson cannot mean *conclusive* evidence by "good reason," since as long as there remain unobserved members of the subject class the evidence for a lawlike²¹ generalization is not conclusive either. He must therefore be making the more audacious claim that observations of a part of the subject class of an accidental universal cannot even make it *probable* that its unobserved members are likewise positive instances. He is then taking the same position as Nelson Goodman, who holds that if "all A are B " is accidental, it does not make sense to say that the evidence that observed members of A are B 's *confirms* the prediction that unobserved members of A are likewise B 's. But this criterion is highly counterintuitive. If 10 apples are picked out of a basket filled with apples and are found to be rotten without exception, it will be inductively rational to predict that the next apple that will be picked is likewise rotten. Yet, it may be just an accidental fact that all the apples in the basket are

rotten. It is not necessary to assume that somebody deliberately filled the basket with rotten apples, though the circumstances may make this hypothesis plausible. It is possible, for instance, that somebody who made random selections (with closed eyes) of apples from a larger basket in order to fill up a smaller basket had the misfortune to get nothing but rotten ones though there were quite a few good specimens in the larger basket.

An attempt to define the law-accident distinction in pragmatic rather than semantic terms, i.e., in terms of the kind of evidence leading one to assert the respective kinds of propositions, while retaining extensional logic for the formulation of the asserted propositions, has likewise been made by R. B. Braithwaite.²² He says as much as that the assertion of a contrary-to-fact conditional causally presupposes acceptance of an instantially confirmed law from which the conditional component (the other component is the negation of the antecedent) is deducible, but that the *truth-condition*²³ of the contrary-to-fact conditional is expressible in extensional logic: $(p \supset q) \cdot \sim p$. There are two major objections to this approach: In the first place, contrary-to-fact conditionals with identical antecedents and contradictory consequents (e.g., "if he had come, he would have been shot," "if he had come, he would not have been shot") are *logically compatible* on this analysis; whereas one should think that their logical incompatibility is a guiding criterion of adequacy for the semantic (not pragmatic) analysis of contrary-to-fact conditionals.²⁴ Braithwaite in fact is saying that all contrary-to-fact conditionals whatever are true, though not all of them would be asserted by people confronted with the choice between asserting or denying them. But if a person honestly denies " p " and is familiar with the conventional meaning of " p ," then he does not believe the proposition expressed by " p "; yet, if the proposition expressed by "if A had happened, B would have happened" is simply the proposition that A did not happen (notice that " $\sim p$ " is logically equivalent to " $\sim p \cdot (p \supset q)$ "), how could anyone who recognizes the conditional as contrary to fact fail to believe it? But secondly, Braithwaite merely postpones the difficulty facing the extensional analysis to the presupposed laws. For, as explained earlier, these may themselves be counterfactual, accepted not because of derivability from instantially confirmed laws but because of extrapolation to an ideal limit. When Galileo asserted that in a vacuum all bodies fall with the same acceleration, he was not led to this asser-

tion by a belief in the derivability of the asserted generalization from "higher level hypotheses." Galileo's law is indeed deducible from "higher level hypotheses," but at least one of these (the law of universal gravitation) was accepted not because of instantial confirmation but just because Galileo's law, together with other "derived laws" (Kepler's laws), was derivable from it.

Braithwaite's extensional analysis of "law", or "lawlike hypothesis", in terms of the notion of a hypothetico-deductive system, is moreover untenable for the following reason. If "all A are B" is supported just by instantial evidence (induction by "simple enumeration"), he says, then it is not lawlike. In order to be lawlike, it must be deducible from well-confirmed higher level hypotheses (it must be supported, in other words, by what Kneale has aptly called "secondary induction"). But since the "highest" hypotheses usually do not admit of instantial confirmation, on account of their postulating entities or events that are not directly observable, what is the condition of their lawlikeness? Braithwaite's answer is that they are lawlike because testable consequences are deducible from them. What it all seems to amount to is that "all A are B"—restricting ourselves, like Braithwaite, to this form of law for the sake of simplification—is lawlike if and only if it is capable of being supported by indirect confirmation, not just by instantial confirmation, i.e., either by instantial confirmation of more general statements from which it follows or by instantial confirmation of less general statements that follow from it. Notice that we need as defining condition indirect confirmability, not actual indirect confirmation, otherwise "lawlike" would be a time-dependent predicate,²⁵ which does not seem to be Braithwaite's intention.

But on this analysis there are no accidental universals at all. Consider, for instance, (1) "all men now in this room are bald," as compared with (2) "all tall men now in this room are bald," where actually some of the men now in this room are tall and some are not. Clearly (2) is deducible from (1), and there is more instantial evidence for (1) than for (2). This is exactly analogous to Braithwaite's argument (*op. cit.*, p. 302) that "all men are mortal" is regarded as a law of nature because it is deducible from "all animals are mortal", for which generalization there is more instantial evidence. And consider this statement: "If . . . there is evidence for [an hypothesis] which is independent of its instances, such as the indirect evidence provided by instances of a

same-level general proposition subsumed along with it under the same higher-level hypothesis, then the general proposition will explain its instances in the sense that it will provide grounds for believing in their truth independently of any direct knowledge of such truth" (p. 303). It is thus that Braithwaite wants to tie the notion of law to the notion of explanation. But he is just engaged in a merry-go-round, since we do not accept a subsumptive syllogism as an explanation unless its major premise is lawlike. Referring back to an example already used, let us assume that not only the inhabitants of green-roofed house H, but also the inhabitants of a house H' which is uniquely describable as, say, the only house in the United States built by a Chinese architect, died before 65 without exception. Then there is more instantial evidence for "all the inhabitants of H or of H' die before 65" than for "all the inhabitants of H die before 65," which follows from the former statement. Yet, we would not accept it as an explanation of the fact that Mr. X died before 65, that he inhabited H and that all inhabitants of H died before that age, if we consider it just *coincidental* that all the inhabitants of H died before 65.

Surprisingly, Braithwaite cites Julius Weinberg²⁶ as giving a similar analysis. But actually there seems to be a fundamental difference in that Weinberg seems to include the belief in a confirmed law from which the singular contrary-to-fact conditional is deducible in the analysis of the latter, whereas Braithwaite takes it, in my terminology, to be causally presupposed by its assertion. Weinberg maintains that "if this vase had been dropped, it would have broken" asserts implicitly "I believe that vases of a given sort break if dropped because I have such and such evidence and I later and independently know a vase of the required sort which has not been dropped." Although I suspect that Weinberg, like other writers on the contrary-to-fact conditional, simply confused the concepts of "causal presupposition" and of "truth-condition" of an assertion,²⁷ it seems to me likely that he used "asserts implicitly" in the sense in which to say "A implicitly asserted q in asserting p" is to say that q is *entailed* by p. Indeed, unless Weinberg meant that such belief statements are entailed by contrary-to-fact conditionals, it would be irrelevant for him to raise, as he does, the question whether belief statements are analyzable by means of extensional logic in connection with the question whether contrary-to-fact conditionals are so analyzable. Now, it is a simple reflection that the contrary-to-fact con-

ditional about the vase could be true in a universe devoid of minds and hence of beliefs; surely "nobody believes that any vases break under any circumstances, but if this vase were dropped it would break" expresses a logical possibility. That the assertion of such a statement is *pragmatically* contradictory is an entirely different matter. Would Weinberg say that a man who asserts that it will rain *implicitly* asserts the proposition that he believes that it will rain because it is unlikely or perhaps even logically impossible—depending on the sense of "assert" (cf. note 11 above)—that he should assert the former proposition unless the latter proposition were true? But surely the propositions that it rains at t and that A does not believe (at a time before t) that it rains at t ²⁸ are logically compatible.

All these considerations point to the conclusion that extensional logic is inadequate for the formulation of laws, and therefore for explicit definition of disposition concepts. If so, an extensionalist who frowns on "causal necessity" as an obscure notion, will have to introduce dispositional predicates into his ideally clear language by means of a device suggested by Carnap some twenty years ago: *reduction sentences*. In order to preclude vacuous applicability of dispositional predicates (cf. p. 198), Carnap, who at that time was firmly committed to the thesis of extensionality, proposed in *Testability and Meaning* to replace explicit definitions of the form $Q_3(x) = (t)(Q_1(x,t) \supset Q_2(x,t))$ by reduction sentences of the form $(x)(t)(Q_1(x,t) \supset (Q_3(x) \equiv Q_2(x,t)))$. Such reduction sentences do, indeed, overcome the paradox of vacuous applicability, since neither " Q_3 " nor " $\sim Q_3$ " is applicable to x if x has not been subjected to the test operation Q_1 . Furthermore, the method of reduction sentences did not, as it might seem at first blush, entail the equally unacceptable consequence that there are no grounds for attributing a disposition to an object prior to performance of the relevant test operation upon it. For, as Carnap pointed out, if Q_1 has been performed upon several members of a class K and led to the result Q_2 , the reduction sentence permits us to ascribe the disposition to them, and hence we may inductively infer that other members of K which have not yet been subjected to Q_1 likewise have that disposition.

Nevertheless, one of my main arguments against D_2 , viz., that it involves a confusion of truth-conditions and conditions of verification, semantic meaning and pragmatic meaning, is equally applicable to Carnap's reduction sentences. My argument was that the intuitive

meaning of dispositional predicates is such that it is logically possible for an object to have a disposition which is never manifested at all. Now, the above reduction sentence does not, indeed, entail that it is *self-contradictory* to suppose that an object has Q_3 while nothing at all satisfies the function " $(\exists t)Q_1x,t$ "; but it entails instead that such a supposition is *meaningless*. Thus Carnap writes in *Testability and Meaning*:²⁹ "If a body b consists of such a substance that for no body of this substance has the test-condition . . . ever been fulfilled, then neither the predicate nor its negation can be attributed to b ." Out of context, this statement is ambiguous. Does it simply mean that on the mentioned conditions we do not know whether or not b has the disposition, but that nevertheless the law of the excluded middle is applicable to the dispositional predicate, i.e., either " Q_3b " or " $\sim Q_3b$ " is true? Or does it mean that both of these formally contradictory sentences are *meaningless* in that case? It seems to me obvious that the principle of empiricism, that synthetic sentences are meaningful only if they are in principle confirmable, together with the method of reduction sentences entails the latter alternative. It is the very essence of a reduction sentence that it determines the meaning of the reduced term only relative to the test condition. By adding further reduction sentences for the same term we can increase its range of significant applicability, but no amount of factual knowledge could ever provide us with grounds for deciding the question whether an object which satisfies none of the alternative test conditions has the property designated by the term if nothing has ever satisfied any of these conditions, in the same sense in which it is *on semantic grounds* undecidable whether or not the square root of two is a prime number: "prime" is *defined* only for natural numbers. Of course, if dispositional predicates were literally "introduced" into a language, without any antecedent meaning, there would be nothing paradoxical about this consequence; it would be just a matter of stipulation how the range of significant application is to be delimited. But I am concerned to criticize the method of reduction sentences as a method of *explicating* the intuitive meanings of dispositional predicates, on the ground that the intuitive meaning of "soluble", for example, is such that it makes sense to suppose that even in a universe in which this disposition is never manifested some things are soluble and some are not.³⁰

It might be supposed that once we abandon the extensional language

and replace material implication by causal implication³¹ for the formulation of "operational" definitions, all these difficulties are easily solved. For the distinctive property of causal implication as compared with material implication is just that the falsity of the antecedent is no ground for inferring the truth of the causal implication. But the defect of D_1 , that it makes the extensions of dispositional predicates undesirably large, would simply give way to the no less serious defect that their extensions are either too large or too small, if the non-extensional definition schema for dispositional predicates took the simple form $Ox, t \rightarrow Rx, t$. For if the arrow signifies that the antecedent predicate designates a property which is *causally sufficient* for the property designated by the consequent predicate, then either everything or nothing has the defined disposition. This follows from the fact that if the antecedent of a causal implication expresses a sufficient condition for the kind of event expressed by the consequent, then *individual constants occur vacuously* in causal implications. " $Oa, t_0 \rightarrow Ra, t_0$ " entails " $Ob, t_0 \rightarrow Rb, t_0$ " and " $Oa, t_1 \rightarrow Ra, t_1$ ", and so forth. Hence, if anything satisfies the definiens at some time, then everything satisfies it at any time, and so everything has the defined disposition at all times. By contraposition, if something does not satisfy the definiens at some time, then nothing satisfies it at any time, and so nothing has the defined disposition.³² Indeed, the test operation by which a disposition is defined is never causally sufficient to bring about the manifestation of the disposition; the effect will occur only if the operation is performed on an object with specified characteristics. Thus, it is "x is immersed in aqua regia and x is gold" which causally implies "x dissolves," not "x is immersed in aqua regia" by itself. This consideration suggests the following improvement³³ on D_2 :

$$Dx =_{df} (\exists f) [fx \cdot (t)(y)(fy \cdot Oy, t \rightarrow Ry, t)] \quad (D_3)$$

It will be noticed that in contrast to D_2 , no instantiation claim is implicit in a dispositional statement according to D_3 —which is all to the good. It is true that Wedberg's objection applies here too: if " $Ox \supset Rx$ " is taken as a value of "fx", then anything satisfies the definiens, since Burks defines "causal implication" in such a way that strict (analytic) implication is a special case of it (Reichenbach's term for this inclusive concept is "nomological implication"). But it is easy to protect D_3 against this popular line of attack by either restricting

the predicate variable to properties which do not satisfy the definiens tautologically, or so defining causal implication that only synthetic implications count as causal.³⁴

Before turning to the major question I wish to discuss in the remainder of this essay, viz., whether the transition to a non-extensional language of causal implication involves an abandonment of Hume's regularity theory of causation and therefore a breach with a basic tenet of empiricism, let us see whether our new definition schema meets the requirement of extensional equivalence of definiendum and definiens. According to it, in ascribing a disposition to an object one asserts that it has some property by virtue of which the reaction R may be predicted to follow realization of test condition O in accordance with a causal law.³⁵ However, the premise that x is subjected to test condition O is insufficient for the prediction of R for two reasons: not only must one ascertain, as already pointed out, that x has a certain intrinsic property, like being gold, or being sugar, or being hydrogen, or having molecular structure H_2SO_4 , but further certain environmental conditions must be fulfilled at the time of the experiment which are usually referred to by the safety clause "other things being equal" if they are not known in detail. For example: suppose we define "x is inflammable" as "x has some intrinsic property (e.g., chemical nature) such that anything with this intrinsic property would burn whenever it is heated." On this definition nothing is inflammable, since the antecedent of the universal causal implication does not mention the presence of oxygen, which is a necessary condition for burning. We need a special variable in order to leave the possibility open that we do not have an exhaustive knowledge of such relevant environmental conditions. We cannot bring them within the range of the same variable as is used for the intrinsic properties, because intrinsic properties are relatively stable, time-independent,³⁶ unlike such transient properties as "being surrounded by oxygen" (consider, for example, the intrinsic property of a sample of gas "being composed of hydrogen molecules": does it even make sense to suppose that the same sample of gas has the property at one time and not at another time?). At any rate, if we express the disposition by a time-independent predicate, we have to use time-independent predicates for the intrinsic properties too, but we need time-dependent predicates for the changeable environmental conditions. Hence the following defini-

tion schema for time-independent dispositions might plausibly be proposed:

$$Dx =_{\text{at}} (\exists \theta)(\exists \psi) [\theta x \cdot (y)(t)(\theta y \cdot \psi y, t \cdot O y, t \rightarrow R y, t)] \quad (D_4)$$

It is true that if we knew all the environmental conditions that are necessary and jointly sufficient for the occurrence of state R in a thing of specified kind θ , the second predicate variable would not be needed. But since the only criterion of the completeness of such knowledge is just that there are no exceptions to the universal causal implication, which it is impossible to know with theoretical certainty, this variable is indispensable for the analysis of disposition concepts in terms of causal implication. On the other hand, if we wish to use "disposition" in such a way that to say that things have dispositions does not entail that their successive states are governed by causal laws but only that they are governed by statistical laws, then we may simply replace causal implication by probability implication in the definiens. The environmental predicate variable would then be unnecessary.

As far as I can see, D_4 is perfectly satisfactory—if we can rest satisfied with the use of the causal arrow as a primitive logical constant. But has Hume written in vain? Should we not at least attempt to reduce the concept of causal implication to the concept of "constant conjunction"? Or is the admission of the inadequacy of extensional logic for the definition of disposition concepts and formulation of contrary-to-fact conditionals tantamount to the admission that causal connection cannot be defined in terms of contingent "constant conjunction"? Several writers have assumed without argument that Hume's regularity theory stands and falls with the possibility of formulating causal laws in an extensional language. Thus Burks writes: "Consider the question: Can causal propositions be adequately translated into an extensional language (e.g. that of *Principia Mathematica*)? The first point to note is that this question is a technical reformulation of a very old metaphysical one: Can the concept of causal connection be defined in terms of ideas of matter-of-fact and constant conjunction, i.e. can causal potentialities be reduced to actualities?"³⁷ Similarly Braithwaite thinks that in order to defend Hume he must show that the use of subjunctive conditionals can be accounted for without surrendering the extensional analysis of "if a thing is A, then it is B" as simply "there are no A's which are not B's."³⁸ I wish to show that this view is mistaken.

According to the regularity theory, to say that the heating of a block of ice (H) causes it to melt (M)⁴⁰ is to say that every instance of H is followed by an instance of M, which implies that not only all past instances of H were followed by an instance of M but also that any future instance of H will be followed by an instance of M. Can this assertion be formulated extensionally? Using "seq(y,x)" for "y follows x", its extensional formulation would read: $(x)(Hx \supset (\exists y)(\text{seq}(y,x) \cdot My))$, where the variables range over events that may be characterized by predicates, such as "being the heating of a block of ice" (H) or "being the melting of a block of ice" (M).⁴¹ Now, according to this formulation, the prediction that any future instance of H is followed by an instance of M would be vacuously true if there were no future instances of H. But the conditional predictions which according to the regularity theory are implicit in any causal judgment are not vacuously confirmable; they are subjunctive conditionals, like "if any instance of H should occur again, it would be followed by an instance of M." As Strawson has pointed out, we do not use "all A are B" in such a way that its truth follows from the nonexistence of A's; rather, if there are no A's, one normally does not attach any truth-value to "all A are B"; and if one does, then not because the subject class is empty, but because the statement was intended as a subjunctive conditional which is indirectly confirmable through inductive reasoning.

Further, that the Humean analysis of causation is not expressible in extensional logic is evident from the consideration that the modal concept of *conceivable circumstances* is needed to express it adequately. This may be shown by analyzing a passage from J. S. Mill, the empiricist who explicitly espoused Hume's doctrine of causation as against the "metaphysicians" who look for mysterious ties in the course of natural events:

When we define the cause of any thing (in the only sense in which the present inquiry has any concern with causes) to be "the antecedent which it invariably follows," we do not use this phrase as exactly synonymous with "the antecedent which it invariably has followed in our past experience." Such a mode of conceiving causation would be liable to the objection very plausibly urged by Dr. Reid, namely, that according to this doctrine night must be the cause of day, and day the cause of night; since these phenomena have invariably succeeded one another from the beginning of the world. But it is necessary to our using the word cause, that we should believe not only that the antecedent always

has been followed by the consequent, but that as long as the present constitution of things endures, it always *will* be so. And this would not be true of day and night. We do not believe that night will be followed by day under all imaginable circumstances, but only that it will be so provided the sun rises above the horizon. . . . This is what writers mean when they say that the notion of cause involves the idea of necessity. If there be any meaning which confessedly belongs to the term necessity, it is *unconditionalness*. . . . That which will be followed by a given consequent when, and only when, some third circumstance also exists, is not the cause, even though no case should ever have occurred in which the phenomenon took place without it.⁴²

Let us see whether this idea of “unconditionalness” can be expressed in extensional terms. Consider the following causal proposition: the lowering of the temperature of a sample of gas G to x degrees causes it to condense. If in fact every instance of the described temperature change is followed by the described effect, we would nevertheless not be justified in calling it the “cause” of the effect, according to Mill’s conception of cause as *unconditionally* invariable antecedent. For we know that the drop of temperature (T) would not be followed by condensation (C) if the gas were not subject to a certain minimal pressure (P). The latter is the “third circumstance” mentioned in the concluding sentence of my citation. Now, if in fact this circumstance accompanies every instance of T, then the extensional implication “ $(x)(Tx \supset (\exists y)(Cy \cdot \text{seq}(y,x)))$ ” is equivalent to the extensional implication “ $(x)(Tx \cdot Px \supset (\exists y)(Cy \cdot \text{seq}(y,x)))$ ”. Therefore, if the assertion of “constant conjunction,” which according to Hume and Mill a causal proposition reduces to, could be expressed extensionally, there would be (on the assumption that every instance of T is in fact accompanied by an instance of P) no ground for identifying the cause of C with the complex condition (T · P) rather than with the simpler condition T. If in fact the earth continues to rotate forever and the sun continues to radiate light forever, then day is an invariable antecedent of night, but it is not an unconditionally invariable antecedent because day would become everlasting on some part of the globe the moment the earth ceased to rotate (provided that solar radiation were to continue). To put it in general terms, even though C may *in fact* be regularly followed by E it may not be a cause of E because the following subjunctive regularity assertion may not be true: if at any time C were to occur, it would be followed by E. And this assertion would be false if another subjunctive regularity assertion

were true: if at any time C were to occur together with C', or in the absence of C", then E would not follow. Notice that the intended meaning of “C is followed by E under all conceivable circumstances” cannot be rendered by “the proposition that C is invariably followed by E holds in all logically possible worlds,” for then the causal law would be logically necessary, which is precisely what Hume and his followers have denied. It rather means “there are no cases of C not being followed by E and there are no conditions C' (logically compatible with C and E) such that C would not be followed by E if C' were present.”⁴³ It is obvious, therefore, that we need the subjunctive conditional in order to give a plausible formulation of the regularity theory, like the one offered by Mill.

It may be replied that once it is admitted that causal propositions do not just assert that such and such conditions are *in fact* always followed by such and such effects, defeat for the regularity theory has been conceded. That one is free to so use the term “regularity theory” that the regularity theory can be true only if causal propositions can be expressed by extensional implications, without the use of non-extensional connectives, cannot be reasonably disputed. Yet, if the core of the regularity theory is taken to be the claim that causal propositions are, explicitly or implicitly, universal propositions which are not logically necessary, i.e., cannot be known by analysis of concepts and application of logical principles alone but are warrantably assertable only on the basis of empirical evidence, then it does not by any means entail extensionalism. To say that the concept “causally (not logically) sufficient condition” cannot be expressed in terms of material implication⁴⁴ is perfectly compatible with saying that a causal law can be known only through inductive generalization or deduction from universal propositions which themselves are knowable only through inductive generalization. That causal laws can be known only, directly or indirectly, on the basis of inductive generalization, may superficially seem to conflict with the “uniformity axiom” of the logic of causal propositions, viz., that any singular causal implication entails the corresponding universal implication. For this suggests the following analogy between causal and logical connection between attributes. If a propositional function “Qx” is logically entailed by a propositional function “Px”, then of course the singular proposition “Qa” is entailed by the singular proposition “Pa”. But conversely, the entailment proposition “‘Pa’ entails ‘Qa’”

entails the entailment proposition “ $(x)(Px \text{ entails } Qx)$ ”. Briefly: individual constants occur vacuously in entailment statements. And as has been explicitly stated by Burks,⁴⁵ the same holds *mutatis mutandis* for causal implication. It is tempting to conclude from this analogy that causal implication is a species of entailment which a superior intellect could discover without the aid of induction.⁴⁶ But he who succumbs to this temptation, simply overlooks that there is absolutely nothing in the logic of causal implication that indicates that there is any other evidential basis for the assertion of a causal implication “ $Pa \rightarrow Qa$ ” than conjunctions like “ $Pb \cdot Qb \cdot Pc \cdot Qc \dots Pn \cdot Qn$ ”;⁴⁷ and the inference from the conjunction to the implication is obviously inductive.

In his careful and instructive article “Dispositional Statements” (*loc. cit.*), Burks invites empiricists to meet the following challenge: “. . . if a philosopher holds that the concept of causal necessity is irreducible to extensional concepts, he should ultimately either show that it is a complex concept or abandon concept-empiricism” (p. 188). Without wishing to commit myself to “empiricism” in all the senses of this term (which I suspect would be a commitment that no lover of consistency could incur), I propose to meet Burks’ challenge by defining “causal implication” in terms of the nonlogical constant “seq”—meaning either just temporal contiguity, so that “action at a distance” would be logically possible, or both temporal and spatial contiguity, as expressed for example by differential laws of motion—together with the logical concept of *natural* implication which is involved in conditional sentences expressing causal connections as well as in conditional sentences that do not express causal connections. Using “NI” for “naturally implies”, we have simply: $Pa \rightarrow Qa =_{df} (x)(Px \text{ NI } (\exists y)(Qy \cdot \text{seq}(y,x)))$. The properties of natural implication may be stated by a set of axioms for natural implication which is like Burks’ except that strict implication is not considered a case of natural implication, i.e., natural implications are contingent statements although they are non-extensional with respect to the constituent statements and predicates. The distinguishing property of natural implication is that the truth of the implication is not entailed by the falsity of its antecedent (resp., by the emptiness of the antecedent predicate), and accordingly “ $p\text{NI}q$ ” is incompatible with “ $p\text{NI}\sim q$ ” provided “ p ” expresses a logical possibility.⁴⁸ Examples of natural implications that are not causal implications are laws of coexistence, as contrasted with laws of succession (dy-

namic laws): all sugar is soluble in water, all ravens are black, and so forth. Notice that a statement of the form “all A are B” is translatable into a natural implication (in the subjunctive mood: for any x , x would be a B if it were an A) only if it is taken to be incompatible with “no A are B.” But, so it may be asked, is not the only condition on which “all A are B” is incompatible with “no A are B” the condition that either statement has existential import? And if so, how can universal contrary-to-fact conditionals like the law of inertia and the other examples adduced earlier be regarded as natural implications in the specified sense?

This argument, however, is based on the assumption that “all A are B” must be analyzable either into “there are no A’s that are not B’s” or into “there are no A’s that are not B’s, and there are A’s.” On the former interpretation, “all A are B” is compatible with “no A are B”—which is counterintuitive; on the latter interpretation there is incompatibility, but on this interpretation “all A are B” cannot express a true contrary-to-fact conditional of universal character. The argument, of course, presupposes that “all A are B” has a clear meaning only if it can be translated into an extensional language, and therefore begs the question. Extensional logic assumes the incompatibility of “all things have P” and “this thing does not have P” (“ $(x)Px$ ” and “ $\sim Pa$ ”) as intuitively evident, and derives the compatibility of “all A are B” and “no A are B” on the basis of an extensional analysis of these statement forms. Since it is thus indispensable anyway that some relations of incompatibility and entailment, like the incompatibility between “everything is P” and “this is not P,” be axiomatically asserted, there can be no objection in principle to our asserting axiomatically that “all A are B” and “no A are B,” taken as natural implications, are incompatible provided it is logically possible that there should be A’s. This intuitive incompatibility derives from the fact that to assert a natural implication is to express a habit of expectation. In saying “if the sun comes out, then it will get warmer” one expresses the habit of associating the idea of rising temperature with the idea of the breaking of sunshine through the cloudy sky, which association of ideas derives, as Hume noted, from a repeated concomitance of the corresponding sense impressions. In saying “if the sun comes out, then it will get colder (and hence not warmer)” one would express the habit of associating the idea of dropping temperature with the idea of increased solar radiation.

But these two habits cannot exist in the same mind at the same time. As an explanation of the origin of the intuitive feeling of incompatibility in question this may seem to be circular: for isn't to say that A has the habit of associating idea I_1 with idea I_2 , to say that if I_1 were evoked in A, then I_2 would also be evoked in A? In other words, isn't to ascribe a habit to a human being to ascribe a disposition to him, and have we not argued that to attribute a disposition to an object is to assert a *natural implication*? However, the point is that the *manifestation* of such a mental disposition consists not just in I_1 being immediately followed by I_2 but also in the occurrence of an introspectable urge or inclination, which Hume called a "gentle force of association." To assert the occurrence of such an inclination is not to assert an implication. And the proposition that a mind cannot, in one and the same phase of its history, be both in the occurrent state described by "inclining from I_1 to some determinate form of non- I_2 " and in the occurrent state described by "inclining from I_1 to I_2 ," is therefore not a special case of the incompatibility of natural implications whose psychological origin is in question.

It seems to me, then, that the use of a primitive concept of natural implication for the formulation of causal connections is perfectly consistent with Hume's theory of causation. I do not know what could be meant by saying that there is a *necessary connection* between antecedent and consequent of a true natural implication, if it does not just mean that in asserting such an implication one manifests a strong habit of association. The statements "if a block of ice is sufficiently heated, then it necessarily melts" and "if any block of ice were at any time sufficiently heated, then it would melt" assert the same fact, however they may differ in emotive pictorial meaning. This insight of Hume and the logical empiricists remains valid, whether or not an extensional analysis of the contrary-to-fact conditional, and therewith of the concept of "disposition", is feasible.

NOTES

¹ In this context "knowledge" is used in the weak sense in which "p is known to be true" entails that there is evidence making it highly probable that p, not the stronger claim that there is evidence making it *certain* that p.

² I have slightly changed Carnap's way of putting the counterintuitive consequence, in accordance with my using "Dx,t" instead of "Dx".

³ There seems to be fairly universal agreement now among philosophers of science that the simple kind of explicit definition of disposition concepts in terms of material

implication is inadequate, precisely because we want to be able to say of an object which is not subjected to the test operation by which a disposition D is defined that it does not have D. One exception to this trend might, however, be noted: Gustav Bergmann maintains ("Comments on Professor Hempel's 'The Concept of Cognitive Significance,'" *Proceedings of the American Academy of Arts and Sciences*, July 1951, pp. 78-86) that such explicit definitions nevertheless provide adequate analyses of the disposition concepts—in a sense of "adequate analysis" which is obscure to me. Referring to Carnap's example of the match which is burned up before ever being immersed in water and therefore would be soluble by the criticized definition of "soluble", he says "I propose to analyze the particular sentence 'the aforementioned match is (was) not soluble' by means of two sentences of the ideal schema, the first corresponding to 'This match is (was) wooden,' the second to the law 'No wooden object is soluble.'" In what sense do these two sentences provide an analysis of "soluble"? Bergmann is simply deducing "the match is not soluble" from two well-confirmed premises, and is therefore perhaps giving a correct explanation of the fact described by the sentence, but since "soluble" reappears in the major premise—as it must if the syllogism is to be valid!—its meaning has not been analyzed at all. It is one thing to give grounds for an assertion, another thing to analyze the asserted proposition.

⁴ See D. J. O'Connor, "The Analysis of Conditional Sentences," *Mind*, July 1951, p. 354. Also, the Finnish philosopher E. Kaila once attempted to escape from Carnap's conclusion that disposition concepts are not explicitly definable by proposing that "Dx" be taken as neither true nor false in case x is not subjected to O (which proposal, incidentally, is consonant with Carnap's proposal of introducing dispositional predicates by reduction sentences, as we shall see later): "Wenn-So," *Theoria*, 1945, Part II.

⁵ This has been called the "paradox of confirmation." See C. G. Hempel, "Studies in the Logic of Confirmation," *Mind*, January, April 1945; and R. Carnap, *Logical Foundations of Probability*, Section 87 (Chicago: Univ. of Chicago Press, 1950).

⁶ For a lucid warning against this confusion, see R. Carnap, "Truth and Confirmation," in H. Feigl and W. Sellars (eds.), *Readings in Philosophical Analysis* (New York: Appleton-Century-Crofts, 1949).

⁷ Indirect confirmation of a conditional is distinguished from (a) direct confirmation, consisting in the verification of the conjunction of antecedent and consequent, (b) vacuous confirmation, consisting in the verification of the negation of the antecedent.

⁸ D is here assumed to be an intrinsic disposition in the sense explained on p. 198. The above schema is, with a slight alteration, copied from Anders Wedberg's "The Logical Construction of the World" (*Theoria*, 1944, Part III, p. 237), who cites it for purposes of criticism from Kaila's *Den maenskliga kunskapen*. A variant of this definition schema has more recently been proposed by Thomas Storer: "On Defining 'Soluble,'" *Analysis*, June 1951.

⁹ The latter restriction has been suggested to me by Michael Scriven.

¹⁰ For example, the painstaking attempt made by B. J. Diggs, in "Counterfactual Conditionals" (*Mind*, October 1952), to achieve an extensional analysis of the counterfactual conditional is guided by this idea.

¹¹ One might, though, take the more moderate view that warranted assertion of counterfactual conditionals merely involves statistical determinism, i.e., belief in the existence of a statistical law relative to which the consequent is inferable from the antecedent with a probability sufficiently high to warrant practical reliance on the conditional. But on either view singular counterfactual conditionals derive their warrant from a law, whether causal or statistical.

¹² Notice that while "A says 'p'" does not entail, but at best confers a high probability upon "A believes that p," the latter proposition is entailed by "A asserts that p,"

according to my usage of "assert" as an intentional verb. I am not denying, of course, that there may be a proper purely behavioristic sense of "assert"; nor do I deny that "A asserts that p" may properly be so used that it is compatible with "A does not believe that p." My usage may be explicated as follows: A believes that p and utters a sentence expressing the proposition that p.

¹³ This seems to be overlooked by O'Connor who, following Broad, concludes his analysis of conditional sentences (*loc. cit.*) with the claim that "a particular contrary-to-fact conditional has exactly the same meaning as the corresponding universal indicative statement." The examples given by him indicate that by the universal statement corresponding to the "particular" contrary-to-fact conditional he means the universal conditional of which the latter is a substitution instance. Obviously, it might be true to say "if the trigger of the gun had been pulled, the gun would have fired" though there are exceptions to the generalization "any gun fires if its trigger is pulled." The singular conditional is elliptical; in asserting it one presupposes the presence in the particular situation of various causal conditions which the antecedent does not explicitly mention. (See, on this point, my article "Philosophical Analysis, Translation Schemas and the Regularity Theory of Causation," *Journal of Philosophy*, October 9, 1952, and my book *Analytische Erkenntnistheorie*, Chapter IV A (Vienna: Springer Verlag, 1955); also R. Chisholm, "Law Statements and Counterfactual Inference," *Analysis*, April 1955).

¹⁴ It might be objected that the law of inertia can be formulated in such a way that it is not contrary to fact: if no unbalanced forces act on a body, then it is at rest or in uniform motion relative to the fixed stars. But when the law is used for the derivation of the orbit of a body moving under the influence of a central force, it is used in the contrary-to-fact formulation since the tangential velocities are computed by making a thought experiment: how would the body move at this moment if the central force ceased to act on it and it moved solely under the influence of its inertia?

¹⁵ For further elaboration of this argument against the extensional interpretation of laws, see my article "Reduction Sentences and Disposition Concepts," in P. A. Schilpp (ed.), *The Philosophy of Rudolf Carnap* (forthcoming).

¹⁶ Notice that a property may fail to be purely general in this sense even if it is not defined in terms of a particular object, e.g., "being the highest mountain."

¹⁷ This criticism applies to C. G. Hempel and P. Oppenheim's explication of "law" relative to a simplified extensional language system, in "Studies in the Logic of Explanation," *Philosophy of Science*, April 1948; reprinted in H. Feigl and M. Brodbeck (eds.), *Readings in the Philosophy of Science* (New York: Appleton-Century-Crofts, 1953). R. Chisholm makes the same criticism, in "Law Statements and Counterfactual Inference," *Analysis*, April 1955.

¹⁸ "A Note on Natural Laws and So-Called 'Contrary-to-Fact Conditionals,'" *Mind*, January 1949.

¹⁹ He could hardly mean it just in the sense of " $(\exists y)(y \in A \cdot x = y)$ ", for this says nothing else than " $x \in A$ ", and so does not amount to one of alternative interpretations of " $x \in A$ ".

²⁰ *Introduction to Logical Theory* (London: Methuen; New York: Wiley, 1952), p. 199.

²¹ A lawlike statement is a statement which expresses a law if it is true.

²² *Scientific Explanation* (Cambridge: Cambridge Univ. Press, 1953), Chapter 9.

²³ The truth-condition of a sentence is that state of affairs whose existence is the necessary and sufficient condition for the truth of the sentence. One might instead speak simply of the proposition expressed by a sentence, if it were not for the purpose of emphasizing the connection between the concepts of truth and of semantic meaning (reference).

²⁴ Strictly speaking, they are incompatible only if the antecedent describes a logical possibility. But contrary-to-fact conditionals with self-contradictory antecedents are

analytic, and we are here concerned only with conditional sentences that express empirical propositions. Cf. the following statement by H. Reichenbach, in *Nomological Statements and Admissible Operations* (Amsterdam: North-Holland Publishing Company, 1953). "Introduction": "Assume we say 'if a had happened, then b would have happened.' If this is to be a reasonable implication, it should be required that the contrary implication 'if a had happened, then not-b would have happened' be not true."

²⁵ A predicate "P" is time-dependent if only statements of the form "x is P at time t," not statements of the form "x is P," are complete.

²⁶ "Contrary-to-Fact Conditionals," *Journal of Philosophy*, January 1951.

²⁷ By the truth-condition of an assertion I mean of course the truth-condition of the asserted sentence.

²⁸ I deliberately use "unusual" tenseless sentences in order not to contaminate propositions with pragmatic properties of assertion events, such as their temporal relation to the asserted facts.

²⁹ *Philosophy of Science*, October 1936, p. 445.

³⁰ A more detailed discussion of reduction sentences, especially in connection with the analytic-synthetic dualism that has been branded a "dogma of empiricism," is contained in my articles "Reduction Sentences and Open Concepts," *Methodos*, Vol. 5, No. 17, and "Reduction Sentences and Disposition Concepts," in P. A. Schilpp (ed.), *The Philosophy of Rudolf Carnap*, forthcoming. See also similar comments by Hempel, in "The Concept of Cognitive Significance: A Reconsideration" (*American Academy of Arts and Sciences*, July 1951; and "A Logical Appraisal of Operationism" (*Scientific Monthly*, October 1954).

³¹ See A. W. Burks, "The Logic of Causal Propositions," *Mind*, July 1951, for an axiomatic definition of causal implication.

³² In "On the Presuppositions of Induction," *Review of Metaphysics*, June 1955, A. W. Burks formulates a "uniformity" axiom to the effect that a universal causal implication is logically equivalent to any substitution instance of itself; or, equivalently, that any two substitution instances of a universal causal implication are equivalent. This is another way of characterizing causal implication, since obviously " $Fa \supset Ga$ " does not entail " $(x)(Fx \supset Gx)$ ".

³³ Cf. A. W. Burks, "Dispositional Statements," *Philosophy of Science*, July 1955. The same non-extensional analysis has been proposed by W. Sellars, in the course of discussions held at the Minnesota Center for Philosophy of Science.

³⁴ For this reason I am not impressed by the defeatist argument presented by Jan Berg in "On Defining Disposition Predicates," *Analysis*, March 1955.

³⁵ It should be noted that my discussion is here restricted to what may be called "causal" dispositions, in contradistinction to what may be called "probabilistic" dispositions.

³⁶ By a time-independent property I here mean a property which a thing has either all the time or never at all. This usage should be distinguished from the usage in which a time-independent property is a property P such that sentences of the form "x has P at time t" are meaningless (thus Carnap argues in "Truth and Confirmation," *op. cit.*, that "true" is time-independent in this sense). To say of a disposition that it is time-independent in the former sense is to assert an empirical law, as explained on p. 198.

³⁷ The schema for time-dependent dispositions, like "electrically charged", "elastic", "kindly disposed toward X", is analogous except that all predicate constants and predicate variables carry the time variable as second argument.

³⁸ "The Logic of Causal Propositions," *op. cit.*, p. 364.

³⁹ *Scientific Explanation*, *op. cit.*, p. 296.

⁴⁰ Following Burks, I shall here assume for the sake of simplicity that what is called the "cause" is a sufficient condition. It is well known that the events which are

actually identified as "causes," both in everyday life and in science, are not strictly sufficient conditions for their alleged effects. For a detailed discussion of problems created by this circumstance for an adequate formulation of an analysis of causal judgments in terms of "constant conjunction," see my article "Philosophical Analysis, Translation Schemas and the Regularity Theory of Causation," *op. cit.*, or my book *Analytische Erkenntnistheorie*, loc. cit.

⁴¹ If we want to express the idea that cause and effect are successive states of the same thing, as in the above example, a more complicated symbolism is needed. But this would not affect the question at issue.

⁴² *System of Logic*, Book III, Chapter V, section 6.

⁴³ C' may be a negative condition, in which case it would be more natural to speak of the necessary absence of a specified condition. For example, in order for the day-night-day sequence to continue it is necessary that no opaque body interpose itself between sun and earth in such a way that no sunlight could reach any part of the earth's surface at any time.

⁴⁴ The following consideration serves as a striking demonstration of the inadequacy of extensional logic for the definition of the concepts "sufficient condition" and "necessary condition" as used in everyday life and science. We often have occasion to say that a certain disjunction of conditions is a necessary condition for a given effect though neither condition by itself is necessary. Thus a college professor may announce to his class that in order to pass his course they must either write a passing term paper or pass a final examination, but that it is not necessary to write a passing term paper, nor is it necessary to pass a final examination. Now, the extensional definition of "q" expresses a necessary condition for "p" is $p \supset q$. Hence the professor's statement would take the form $(p \supset q \vee r) \cdot \sim(p \supset q) \cdot \sim(p \supset r)$. But since this conjunction entails $(p \cdot \sim q \cdot \sim r)$, which contradicts the first conjunct, it is self-contradictory!

⁴⁵ Cf. "On the Presuppositions of Induction," *Review of Metaphysics*, June 1955.

⁴⁶ This seems to be the view W. Kneale takes of laws of nature. As Kneale himself notes in *Probability and Induction* (Oxford: The Clarendon Press, 1949), p. 71, the view was held by Locke: though man cannot attain to certain knowledge of the laws of nature, as he can only generalize from instances, an angel who knew the "real essences" of natural kinds would see the same sort of necessary connection between causal antecedent and causal consequent as we see between "being a Euclidean triangle" and "being a triangle whose angle-sum equals 180°."

⁴⁷ Of course we may justifiably assert " $Pa \rightarrow Qa$ " even if no instance of P has ever been observed, on the evidence " $Ra \cdot Qa \cdot Rb \cdot Qb$ " etc., where P and R are similar properties (e.g., let $Px = x$ is water subjected to a temperature exceeding 150°, and $Rx = x$ is coffee subjected to a temperature exceeding 155° and $Qx = x$ boils).

⁴⁸ In Burks' system the specified incompatibility, moreover, holds only if the antecedent is physically possible; accordingly there are paradoxes of causal implication analogous to the familiar paradoxes of material and strict implication. This additional proviso, however, has such queer consequences as that "if ice were denser than water, it would not float" and "if ice were denser than water, it would still float" are compatible.

Counterfactuals, Dispositions, and the Causal Modalities

Introduction

(i) Although the following essay attempts to deal in a connected way with a number of connected conceptual tangles, it is by no means monolithic in design. It divides roughly in two, with the first half (Parts I and II) devoted to certain puzzles which have their source in a misunderstanding of the more specific structure of the language in which we describe and explain natural phenomena; while the second half (Parts III and IV) attempts to resolve the more sweeping controversy over the nature of the connection between 'cause' and 'effect,' or, in modern dress, the logical status of 'lawlike statements.'

(ii) The essay begins with a case analysis of a puzzle, taken from recent philosophical literature, relating to the analysis of counterfactual conditionals, statements of the form "If that lump of salt had been put in water, it would have dissolved." The diagnosis of this puzzle, which occupies the whole of Part I, shows it to rest on a misunderstanding of the conceptual framework in terms of which we speak of what *things do* when acted upon in certain ways in certain kinds of circumstance. Although the puzzle is initially posed in terms of examples taken from everyday life, the logical features of these examples which, misunderstood, generate the puzzle, are to be found in even the more theoretical levels of the language of science, and the puzzle is as much at home in the one place as in the other. For the framework in which *things* of various kinds (e.g. matches, white rats) behave ('respond') in various ways (catch fire, leap at a door) when acted upon ('submitted to such and such stimuli') under given conditions (presence of oxygen, 24 hours of food deprivation) is far more basic than the distinctions between metrical and non-metrical concepts, molar and micro-things,