COHERENTIAL VALIDATION OF CAUSALITY*

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1. *Introduction*

The concept of causality, extensively studied throughout the history of philosophy, has acquired a wide range of meanings. In this paper, care will be taken to not lose sight of the actual connotations which such an idea has in science, for it must be acknowledged that the concept of cause forms an integral part of scientific assertions. Indeed, the task is to elucidate the criteria for establishing causal relationships that are actually used in science. Therefore, causality will be discussed within the context defined by the theory of knowledge; the metaphysical idea of causation as well as the other extreme, a somewhat subjective notion of causal relationships that relies on common sense, are set aside without refutation or acceptance.

The classical empiricist point of view as propounded by Hume (1960) asserts that a singular statement of the form "*H* because *b*" implies the existence of a 'natural law' such that "all objects of class *H* follow as a consequence from those objects of class *b*"; accordingly, we have reason to believe in the truth of an assertion only in so far as we believe that there is a law that supports it. Hume's concept of natural law can be understood as a constant relationship between phenomena. He defined cause to be:

> an object, followed by another, and where all the ob-

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jects similar to the first are followed by objects similar to the second (p. 220).

Ducasse (1951, 1968, 1969) has been the most effective critic of Hume's views on causality and has advanced a theory of his own. He defines causality as follows (Harré and Madden, 1975):

> Causation is the observable relation which obtains between the three terms of any strict experiment: If, in a given state of affairs *S*, *only two* changes (whether simple or complex) occur during a given period, one of them *E* occurring immediately after and adjacent to the other *C*, then *eo ipso*, *C* proximately *caused* *E*, and *E* was the proximate effect of *C* (p. 16).

Ducasse maintained, at variance with Hume, that singular statements concerning causality can be made without the backing of a law.

Davidson (1967) takes a conciliatory attitude in stating that it is advisable to make a distinction between knowledge of the existence of a law which is the link between two events *b* and *H*, and an in-depth acquaintance with the law itself. According to Davidson, Ducasse is right in that the truth of a singular statement of causality can be affirmed without reference to a law, but Hume is right as well, in stating that there is a natural law corresponding to a particular causal assertion.

The thesis examined here holds that a law is a necessary element of statements regarding a causal relationship; however, the definition of what constitutes a law differs from that of Hume, Ducasse, and Davidson. For these philosophers, a law is a generalization of particular cases, so that from the known repeatability of identical individual phenomena, the general principle may be inferred. In contrast, the coherential theory presented in this paper maintains that a law may be considered as such both because it is part of a model or theory and because it is confirmed or corroborated through experiment or observation.

The predictive (and 'retrodictive') power of science is rooted in its ability to elaborate theories which are both coherent and experimentally 'testable' or 'falsifiable' in a Popperian sense[1] (Popper, 1965). According to this view, the growth of science is not accomplished by inductive reasoning but by the development of theories; specifically, by extending or correcting them when new factual information becomes available. Postulated laws of nature are only temporarily acceptable until new incompatible data are presented which force their rejection. It is precisely the concept of theory and the consequent elaboration of the idea of model which are useful in establishing criteria for judging the validity of the use of 'because', not in the nonobjective sense of the word, but in a scientific sense; that is to say, arguable and susceptible of corroboration. The matter will be discussed as it concerns science in general, but it appears to be particularly relevant to biology and medicine in that: a) the concept of causality more frequently has a direct bearing on explanations in these fields than in physics, where the concept is likely to be hidden by sophisticated mathematical formulations, and b) the concept of causality in the former areas often is expressed as a somewhat vague statement about relationships between events. However, far from having lost its usefulness as has been claimed (Abbagnano, 1961), causation is a notion which appears to be inseparably united to the structure of science.

2. *Elements of a phenomenon*

The following are two examples of phenomena which will be used in order to initiate the arguments:

A, Example of the indicator. A colorless[2] liquid re-

[1] The coherential theory set forth in this essay has immediate antecedents in Popper (1965) and Rischer (1973).

[2] Phrases and words like "colorless", "without indicator" (see Table I) are

agent, upon being mixed with colorless indicator fluid, turns red.

B, *Example of the smoker.* A man acquires the habit of smoking in his youth and develops a bronchogenic carcinoma in middle age.

From these two instances, features have been selected and listed in Table 1 which are relevant to the argument to be developed.

TABLE 1

TWO EXAMPLES OF CAUSALITY: RELEVANT FEATURES AND THEIR SYMBOLS

Symbols	*Features*	*Example A*	*Example B*
e	object	liquid reagent	man
F	initial property	colorless	healthy
H	final property	red color	cancerous
a	initial condition	without indicator	nonsmoking
b	final condition	with indicator	smoking

$$F(e)\, Y\, a \xrightarrow{c} H(e)\, Y\, b \qquad \text{I}$$

A 'phenomenon' can be expressed using the features and their symbols as indicated in Table 1:

This is read as: "An object e has the property F in an initial condition a such that when a final condition b is introduced, the property H is produced, taking the place of property F in the object e." The arrow c signifies the rule governing the correspondence between the two parts of the expression. The symbol Y means condition (frame of reference, circumstance, etc.).[3] There are two conditions: 'initial'

used as convenient expressions which though being negative, suggest an affirmation. Thus, "colorless" should be taken to mean "transparent", while "without indicator" suggests a relevant physical condition of certain reagents in solution.

[3] The symbol 'Y' is my own and designates a 'circumstantial operator', signifying the context, domain, or realm of discourse in which a proposition is affirmed or negated. It is read: "in the realm of...", "in the context of...",

(a) and 'final' (b). The expression merely indicates a correspondence between the properties of object e in frame of reference (or condition) a and the properties of the same object in frame of reference b. The expression has, consequently, the logical value of a mathematical 'mapping' in which the final property is the 'image' of the initial property.

The main point of this essay is that c is a law forming part of an ordered set of statements called a model.

A useful definition of law formulated by Bunge (1973) states that:

> a law (i) is a *general* statement in some respect, (ii) has been empirically *confirmed* in a mode satisfactory to some domain and (iii) belongs to some *scientific* system (model, theory).

One may conceive of some scientific assertions which, although included in a model, are not laws since condition (ii) is not satisfied. The following conditions are imposed upon a model:

> *Unity*. Certain basic laws and other scientific statements can be combined to give rise to statements of a higher order and these, in turn, may be combined again. This process can be repeated until a unique statement is reached which is the model itself. Moreover, models are combined to form theories and these can be assembled to form theories of a more comprehensive nature.
>
> *Probability*. The laws and other statements which compose a model are expressed in such a way that proofs

"in the frame of reference of...", etc. Thus, comparisons can be made between that which is affirmed or negated in varying contexts. The statement p Ұ a is understood as "p is true within the context of a"; likewise, p Ұ $a \cdot \overline{p}$ Ұ b is read "p is true in context a but not in context b". For instance, the latter expression could represent the assertion "one-eyed John is king, p, in the kingdom of the blind, a, but not in the kingdom of the sighted, b". The circumstantial operator may indicate time as well, as in the phrase "the sun e shines s at noon t": $s(e)$ Ұ t.

can be devised or logical contradictions can be detected by comparing any pair of statements at each level of generality and between levels.

Coherence. Contradictions are not found between any pair of statements which form part of a model. It can therefore be said that a statement is truthful from a formal point of view, since it is not contradictory but rather is complementary to any other statement within the model.

Uncertainty. There always exists the possibility that a model includes factually false statements which do not interfere with the model's coherence. Such statements can only be detected through observation and/or experimentation. When a statement is corroborated by experimental results, it reaches the status of a law.

Testability. A model includes a set of statements capable of being experimentally or observationally tested. However, not all statements are required to be susceptible of factual testing.

Under the condition of probability, the coherence of a model and hence the formal truth of a law, c_i, can be affirmed if and only if it is not the case that the law c_i is contradictory to another law c_j or any statement within the model. Consequently, a model must be rejected (or modified) whenever any law c_i is found contradictory to any other law c_j and/or statement within the model. Under the condition of testability, the factual truth of at least some of the statements in a model can be affirmed and thus raised to the status of a law if and only if it is the case that by observation or experimentation it is found that "F is the property of e under initial condition a and that F changes into property H under final condition b". However, scientific truth is not a dual concept; the terms 'formal truth' and 'factual truth' are shorthand names for a statement affirmed in a formal context and a statement ascertained in a factual context, respectively.

It is of fundamental importance that the formal and the factual are frequently contrasted; hence, it is imperative that posited relationships of causality are based on models. Assertions and observations are open to discussion, and thus are objective, only in so far as they are validated with respect to models. Common knowledge is distinguished from scientific knowledge in that the latter involves the use of models which ultimately confers the property of objectivity on this knowledge.

Duhem (1962) had already formulated the core of this thesis when he stated that a law is a symbolic relationship whose application to concrete reality requires that a set of theories is known and accepted.

The concept of symbolism and the coordination of reality and symbolism have been discussed more recently by Born (1964).

3. *Definitions*

At this juncture, the following three definitions can be introduced:

> *Phenomenon.* There is a phenomenon if and only if (i) two properties F and H are attributed by a model statement to a unique object e in two distinguishable conditions: initial, a, and final, b, respectively; and (ii) the two attributed properties of the object e and the corresponding conditions are ascertained by actual observation and/or experimentation. Accordingly, F and H are the initial and final properties, respectively.
>
> *Condition of an object.* Given an object e exhibiting a set of properties G, u is the condition of the object if and only if (i) u is stated in a model to be a property which taken as a whole is attributed to a set of objects to which e belongs such that both G and u are bounded within a space-time continuum of some defined magnitude; and (ii) both G and u are ascertained by observation or experimentation to be actually confined within a defined space-time continuum.

Cause. Given a phenomenon, its cause is equivalent to the object's final condition.

4. *Some problems and further examples*

Many difficulties are encountered by theories of knowledge that are based on the assumption that causal relationships between events can be grasped directly by careful observation and strict experimentation, or even by means of common sense, as if such relationships were facts in the strictly empirical sense of the word. These problems do not arise when causal relationships are stated as postulates in a coherent model, and thus are open to experimental or observational testing which can lead to eventual corroboration or refutation. Some issues related to the concept of causality will now be discussed.

First, one important task of science is to discriminate between mere coincidence or correlation and genuine causality. For instance, consider the following example: An astrologist (Gleadow, 1968) pointed out that the eruption of the volcano Krakatoa in 1883 coincided with the entrance of the moon into Capricorn, and suggested that this cosmological event was often associated with disasters and natural catastrophes. He then found a new astrological frame of reference, the position of Saturn exactly on the horizon, which permitted correlations to be established with a much greater accuracy than was achieved with the previous calculations. In agreement with his proposal, 14 of the 126 worst mining accidents did indeed coincide with the predicted position of Saturn with a high degree of statistical significance (the odds against this happening by chance were calculated at 100,000 to 1). Many scientists would trust the correlation, but would not be convinced that a causal relationship had been established since astrology as a whole is not coherently integrated with cosmological theories, and in many respects the two realms are incompatible.

Second, two happenings could regularly follow one another and yet not be causally related. Thus, using the notation of expression I, the events night and day may be described as follows:

$$\text{Day } (e)\mathfrak{Y}\, a \xrightarrow{\mathfrak{C}} \textit{Night } (e)\mathfrak{Y}\, b$$

A naive observer would say that day is the cause of night, that is, night is the effect of day; or he might say that night is the cause of day. Yet, the cause of night is *b*, a condition or property of a number of objects taken as a whole: the sun's position relative to the earth's surface and the characteristics of light propagation result in the location of objects in an earth-casted shadow. Some aspects of property *b* might be grasped directly as a fact, but in order to understand *b* as a cause, it must be postulated in a model.

Third, both cause and effect are confined, so to speak, within a definite period of time. If condition *b* is present during period t_b and nothing happens to object *e* whose property is *F* in that time, there can hardly be posited a causal relationship between *b* and a new property *H* of the same object *e* during a subsequent period t_{b+1}. For instance, when someone strikes a match at time t_b and nothing happens to the match, then the match would not be expected to light at time t_{b+1}. The match would light at time t_{b+1} following its striking at time t_b only if something had happened to it at t_b while it was being struck. There is an 'interesting' property (or interesting effect) such as lighting as well as a set of 'noninteresting' properties such as the chemical reactions preceding lighting. Then the whole event is assumed to occur at a period from t_b to t_{b+1}.

This example raises the psychophysiological questions of how the human mind perceives causal events, and in particular, how 'interesting' happenings are preferentially perceived over 'noninteresting' ones, how durations are defined, and so forth. These issues will not be dealt with here. The point is that similar questions might be raised in connection with the scientific observation of phenomena, but then they become methodological matters: how durations are limited in experimental setups; what are the criteria for measuring space and time; how to detect the interesting properties and their magnitude without interfering with the noninteresting properties, etc. What scientists actually do is to hypothesize about the properties they want to record and measure, arrange experimental conditions according to the hypothesis, and carefully calibrate their instruments so that time and space are sharply defined. In order to design their experiments, scientists are guided by a model, however provisional and perfectible it may be.

Fourth, the world appears as a continuous succession of happenings in which the scientist is bound to find regularities. Many events take place simultaneously making the task of identifying causes and effects a formidable one. For instance, consider the regular cycles of nature which quite often occur in phase. The turning of the earth on its axis, the movement of the earth with respect to the sun, the moon revolving around the earth, the ocean tides: all are interrelated cycles. There are also the so-called 'biological clocks', a coined term referring to a rather large number of phenomena in living creatures characterized, among other properties, by regular cyclic behavior. The biological clocks are synchronized, in turn, with sidereal rhythms.

In such a state of affairs, it would be nearly impossible for a naive observer to isolate an event occurring immediately after another event in order to determine which was the cause and which the effect. Using only his senses, he will perhaps come to the conclusion that a certain biological clock is causing the tides or that the tides are causing the phases of the moon. However, he would be equally justified in claiming that the tides cause the biological rhythms or that the moon causes the tides. For that matter, all possible permutations of paired cyclic events could become conceptually linked by a claimed relation of causality. However, this is not the method actually used by scientists.

Again, a scientist would construct models, no matter how mistaken they are at the beginning, and correct them in the light of experimental or observational results, thus creating better and better models, and permitting more refined observations. During this process, he would discover reasonable causal relationships. Certain biological clocks could be isolated in the laboratory which still continue to exhibit cycles mirroring those of the tides, but which are not directly related. He may have initially supposed that the tidal rhythm was the master clock of the biological clock, but following further experimentation and observation, he may postulate that the biological clock in question is endowed with its own timing devices, but is susceptible to adjustment according to the cycles found in its natural environment.

5. *Degrees of plausibility*

The use of certain apparently vague or ambiguous expressions regarding state changes is customary in scientific reports, especially in the areas of biology or the social sciences; however, these expressions do not necessarily convey the notion of causality understood as a vague relationship. Rather, a level of plausibility (or acceptability) is often expressed with regard to the factual or formal truth of these causal relationships. Such vague statements are of the form: "It is suggested that *H* because *b*, given that *c*." This type of relationship may provisionally be called 'quasicausality', notwithstanding that *c* is postulated as a law.

Using bivalent logic, the value of either 1 or 0 can be assigned to formal or factual propositions. However, in order to express the relationship of quasicausality, it is necessary to assign values, expressed as fractions, between 0 and 1. A proposition is then said to be truthful when it corresponds to a fraction whose value is 'close to 1', indicated by the symbol $\ddot{1}$; likewise, a proposition is said to be false when it corresponds to a fraction whose value is 'close to 0', expressed by the symbol $\ddot{0}$.

The problematical issues of whether these fractions are probabilities or the means by which they can be assigned will not be tackled here. Nevertheless, it is fitting to mention in relation to the second point that one of the functions of scientific societies, academies, editorial boards, and congresses is to arrive at a consensus with respect to acceptable standards of exactitude for observations and results, and to judge the coherence, unity, etc., of models. Although frequently no explicit evaluation is made of written articles or orally delivered papers, a judgment of acceptability is implicitly given, which for the purposes of the present discussion is equivalent to ï or ö. Hence, the necessity for measurements —the more exact the better— as well as the importance of norms, the utilization of experimental animals of known genetic strains and pure cell lines, etc., in order to obtain results which can be compared between laboratories and individuals.

The point important for our argument is that once it is accepted that truth or falsehood, both formal and factual, may be defined according to certain degrees of conventional acceptability such as ï or ö, bivalent logic can then be used in the calculation of these values. Therefore, the same reasoning can be applied to quasicausality as to causality. In fact, the term quasicausality may be dispensed with at this time, leaving the term causality which now refers to somewhat vague or ambiguous scientific statements which, however, are acceptable within the defined limits of tolerance. Given that the limits of ambiguity can be objectively described, the previous epistemological considerations with regard to the validity of causal relationships need not be greatly altered.

6. *Alternative causality*

Consider the following example:

> A nerve fiber *e* has a resting state *F* in circumstance *a* which can be altered by the application of an electrical pulse *b 1*, a temperature change *b 2*, a mechanical shock *b 3*, ... b_n; or a combination of two or more of these agents, thus generating an impulse *H*.

This example illustrates the situation of alternative causality. An electrical pulse, a mechanical shock, a sharp change in temperature, etc., are all stimuli, that is, causes which bring about the generation of an action potential (or nerve impulse) by the nerve fiber. Alternative causality can be explained by the coherential theory as a family of causal relationships with the following form:

$$F(e)Y\,a \xrightarrow{c_{b1}} H(e)Y\,b\,1$$

$$F(e)Y\,a \xrightarrow{c_{b2}} H(e)Y\,b\,2$$

$$\vdots \qquad \text{II}$$

$$F(e)Y\,a \xrightarrow{c_{bn}} H(e)Y\,b\,n$$

Each expression is an alternative causal relationship which is based on alternative laws such as $c_{b1} \vee c_{b2} \vee \ldots \vee c_{bn}$.

Accordingly, there is at least a causal relationship supported by the law c_{bi} which is true. These expressions do not exclude the postulation of various causes which could simultaneously coincide to produce a phenomenon. The point is that causality can be expressed by a phrase of the form "*H* because *b*, given that c_{bi}". Furthermore, laws such as c_{b1}, $c_{b2} \ldots c_{bn}$ form a class, a conceptual entity, itself a law of higher order, denoted as c^z. This is a relationship of 'inclusive causality', in which the cause is represented by *b i*, whose general formulation is:

$$F(e)Y\,a \xrightarrow{c^z} H(e)Y\,b\,i \qquad \text{III}$$

Applying this expression to the above example, it can be read as:

A nerve fiber *e* has a resting state *F* in circumstance *a* which is altered upon the application of a *stimulus bi* in such a way that the fiber generates an impulse *H*.

The word 'stimulus' is the name of a class *z*, formed by *b1, b2 . . . bn,* such that the series forms a totality. A law or principle of excitability, c^z, could be formulated once the phenomena are integrated into a model of membrane mechanisms including ionic flows, etc.

Few would deny that models generally develop to account for the apparently multiple (even disparate) detectable causes of a phenomenon, thereby aiding in the formulation of explanations. This is particularly true in biology where owing to the complexity of the systems, the investigator often has to content himself with *ad hoc* explanations, though always hoping to arrive at general and coherent explanations.

7. *Causality and probability*

Causality and probability are customarily considered to be incompatible. However, from the coherential point of view, they are complementary. In effect, probability is a mathematical or logical (Ayer, 1957) instrument which is used to assign degrees of doubt or uncertainty with respect to certain phenomena or state changes. Probabilities are fractional values between 0 and 1; the closer to 0, the greater the doubt.

In order to explain the origin of these doubts, the concepts of 'overt properties' and 'hidden properties' of phenomena as well as of 'overt and hidden initial conditions' and 'overt and hidden final conditions' must be introduced. Properties or conditions are defined as 'hidden' if (a) they are not accessible to observation or experimentation in the present (though they may become so in the future), and if (b) they are included in the formulation of laws relevant to the causal explanation in question.

Doubts arise with respect to causation when either properties or conditions are not accessible to observation, although they are postulated in a model. Hence, there are two forms of 'doubtful causality': one which refers to initial and final properties, and another which refers to initial and final conditions. The first form may be symbolically expressed as follows:

$$F \cdot S(e)\text{Ɏ}\, a \xrightarrow{c} H \cdot S(e)\text{Ɏ}\, b \qquad \text{IV}$$

where F and H are sets of overt properties and S is a set of hidden properties.

The second form has three variations:

$$F(e)\text{Ɏ}\, ak \xrightarrow{c} H(e)\text{Ɏ}\, b\, l \qquad \text{V}$$

$$F(e)\text{Ɏ}\, ak \xrightarrow{c} H(e)\text{Ɏ}\, b \qquad \text{VI}$$

$$F(e)\text{Ɏ}\, a \xrightarrow{c} H(e)\text{Ɏ}\, b\, l \qquad \text{VII}$$

where k and l represent sets of hidden conditions.

Two examples of doubtful causality now follow:

> *Example of the first form* (IV). A mouse e (of strain S) exhibits normal brain waves and behavior F in initial circumstance a, but upon being subjected to an intense sound b, it develops a convulsive crisis H. This is due to the fact that mice of strain S, and only of strain S, have a susceptibility . . . etc.

This explanation concerning a state change is 'without doubt' if the information between parentheses is available, but must be assigned a probability P if this datum is not known but only postulated in the model. The model itself should provide the rules for the calculation of P.

> *Example of the second form* (VII). A man e in good health F leaves his parasite-free hometown a and visits place b (infested with *Plasmodium* parasites and anopheles mosquitoes, l). On his return, he develops a high fever including delirium, H.

The information in parentheses would probably be inaccessible to a doctor just arriving at the patient's bedside, who could then make only a tentative diagnosis. The doctor would assign a higher probability to the diagnosis of malaria once he had access to the 'hidden property'.

Thus, a causal relationship is based on laws and statements coherently arranged into models, but it remains necessary to assign probabilities to certain phenomena such as have been described in this section.

8. *Statistical causality*

More complex relationships arise when statistical effects assumed to occur at the microscopic level are invoked to explain macroscopic phenomena. The following example will be used to illustrate this situation:

> Two compartments divided by a semipermeable membrane display no difference in osmotic pressure, *F*, when each compartment is filled with distilled water, *a*, but upon the addition of solute to one of the chambers, *b*, there appears a measurable difference in osmotic pressure, *H*.

Since according to the coherential theory causation should only be discussed in terms of a model, statistical statements regarding both macroscopic and microscopic events must be included in the model. For instance, in the above example, the following 'microscopic statement' is in order: "Under condition *a* there is an equal number of impacts of water molecules per unit time on either side of the membrane surface, while there is a greater number of such impacts per unit time on one side of the surface as compared to the other under condition *b*."

An interesting type of statistical causality is exemplified by the phenomenon of Brownian motion. A combination of 'multiple causality' and 'doubtful causality' of the second type is involved and may be symbolically expressed as follows:

$$F(e)\mathcal{X}\ (a \cdot k_1 \vee a \cdot k_2 \vee \ldots \vee a \cdot k_n) \xrightarrow{c^z} H(e)\mathcal{X}\ (b \cdot l_1 \vee b \cdot l_2 \vee \ldots \vee b \cdot l_n) \qquad \text{VIII}$$

The causal relationships in Brownian motion may be verbally expressed as follows: "A microscopic particle e located in a spatio-temporal position F in a liquid is subjected to forces $a \cdot k_1$ and/or $a \cdot k_2$ and/or ... and/or $a \cdot k_n$. Each $a \cdot k_i$ is produced by a collision between a molecule and the particle. When the particle is subjected to forces $b \cdot l_1$ and/or $b \cdot l_2$ and/or...and/or $b \cdot l_n$ due to collisions with other molecules, position H is achieved in the liquid due to acceleration. . . ."

Expression VIII indicates one or more possible initial conditions of the form $a \cdot k_i$ and one or more causes of the form $b \cdot l_i$ for each state change, where both k_i and l_i are hidden conditions. The law c^z is of the type discussed above for cases of alternative causality.

Several combinations of the different types of doubtful causality that have been mentioned can be involved in statistical phenomena. For instance, after counting the number of smokers and nonsmokers in an epidemiological study on lung cancer, the following assertion is made: "The majority of those people who developed lung cancer probably contracted the disease because they smoked, but a significant percentage of people who developed lung cancer have never smoked." In this example, there is an assertion of actual causation as regards the smokers, since the mechanisms involved are presumably specified in the model. However, the assertion concerning nonsmokers remains merely a descriptive one until additional assertions (laws) about the mechanisms involved, either genetic, toxicologic or others, are specified in the model.

RESUMEN

Según el punto de vista empirista se sostiene que la proposición '*H* porque *b*' conlleva la afirmación de una ley de la forma: 'todos los objetos de la clase *H* se siguen como una consecuencia de los objetos de la clase *b*'. La verdad de la ley se infiere de la observación de múltiples instancias particulares. Algunos pensadores, ateniéndose al sentido común realista, afirman que la causalidad se expresa por proposiciones de la forma '*H* porque *b*', donde *H* y *b* son dos sucesos (eventos), y la palabra 'porque' significa la relación entre ellos, sin necesidad de asentar definición o explicación alguna de esa relación. Por consiguiente afirman que podemos aprehender asertos singulares de la forma '*H* porque *b*' sin que a éstos los respalde una ley. Y en fin, un punto de vista ecléctico es que aunque a la causalidad la respalda una ley, aquella puede ser afirmada sin referencia a ésta.

La tesis del presente ensayo es que la ley es un elemento necesario en las proposiciones de causalidad. Pero esta postura difiere radicalmente de las mencionadas por cuanto al significado de ley se refiere. Se sostiene aquí que una ley es tal, sólo por cuanto: (a) es un aserto 'coherente', es decir, no es contrario ni contradictorio con respecto a otros asertos correlativos, de modo que todos en su conjunto constituyen una teoría o modelo; y (b) es un aserto susceptible de corroboración o refutación mediante el experimento, o la observación. El atributo de 'coherente' o 'congruente' de toda ley es toral en la discusión de este ensayo acerca de los problemas que plantea la noción de causalidad.

A fin de desarrollar la tesis se recurre a la siguiente expresión simbólica:

$$F(e) Y\, a \xrightarrow{\;c\;} H(e) Y\, b$$

la cual se lee 'un objeto *e* tiene la propiedad *F* en la condición *a*, de suerte que cuando se introduce una condición final *b* la propiedad *H* se produce en el objeto *e* sustituyendo a la propiedad *F*'. La correspondencia entre $F(e) Y\, a$ y $H(e) Y\, b$ se establece mediante un elemento, pero éste no es el nombre de un fenómeno o su descripción, sino que es una ley, que es científica por ser parte de un modelo bien formado.

De conformidad con esta teoría coherencial de la causalidad se discute: (a) la diferencia entre la mera correlación de sucesos u objetos y la genuina causalidad; (b) la verificabilidad de las leyes y

modelos; (c) los niveles de verdad científica (plausibilidad o satisfactoriedad de los asertos y conclusiones científicas); (d) la causalidad alterna; (e) el problema causalidad-probabilidad; y (f) la causalidad estadística.

Las cuestiones mencionadas tienen que ver con la ciencia en general de manera muy directa y vital, pero parecen particularmente relevantes en la biología y la medicina. En la física, las formulaciones matemáticas, a menudo muy exactas y elaboradas, de cierto modo ocultan la noción de causalidad y los problemas que plantea.

[*F. A.*]

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