PROBABILISTIC CAUSALITY AND IDEALIZATION

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Abstract

The main aim of this paper is to provide some probabilistic notions on causality proposed to be applied to the nomic statements which intend to give account of the indeterministic processes within the domain of a scientific theory. In general, such statements are, in more or less extent, idealized statements which rest on a variety of unrealistic suppositions. I try to show how the probability distribution over the final states of an indeterministic process changes accordingly as the nomic statement in question is de-idealized by means of addition of the causally relevant factors. In order to illustrate the study I take few nomic statements from population genetics. Besides, in the course, I attempt to contrast the ideas embraced here with some of the notions of Humphreys´ ontic conceptions of causality and explanation, which are contrary to the epistemic view adopted here about those subjects.

Keywords: *Probabilistic causality; indeterministic process; idealized laws; concretization; probabilistic explanation.*

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Causalidad probabilista e idealización

Resumen

El propósito principal de este artículo consiste en proveer algunas nociones probabilistas sobre la causalidad, propuestas para aplicarlas a enunciados nómicos que pretenden dar cuenta de procesos indeterministas en el dominio de una teoría científica. En general, tales enunciados son, en menor o mayor grado, enunciados idealizados que descansan sobre una variedad de suposiciones irrealistas. Intento mostrar cómo cambia la distribución de probabilidad sobre los estados finales de un proceso indeterminista en la medida que el enunciado nómico en consideración se desidealiza por medio de la adición de factores causalmente relevantes. Para ilustrar el estudio considero unos cuantos enunciados nómicos de la genética de poblaciones. Además, en el curso, pretendo contrastar las ideas aquí elaboradas con algunas nociones de las concepciones ónticas de la causalidad y la explicación debidas a Humphreys que son contrarias al enfoque epistémico que adopto sobre esas temáticas.

Palabras clave: *causalidad probabilista; proceso indeterminista; leyes idealizadas; concretización; explicación probabilista.*

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Introduction

Most of the philosophers who have dealt with the issue of probabilistic causality have analyzed simple statements of the form $P(A \mid B) > P(A)$ − given an implicit class of reference. Since the classic monograph by Patrick Suppes, *A Probabilistic Theory of Causality* (1970), the main idea of this kind of theories has been that the occurrence of event B rise the probability of occurrence of event A (see, for example, Rosen 1982-83, Eells & Sober 1983, Eells (1980), Salmon (1980) and Davis 1988). Suppes introduce, first, the notion of prima facie cause as following: "The event $B_{t'}$ is a *prima facie* cause of the event A_t if and only if $P(A_t \mid B_{t'}) > P(A_t)$, where $P(B_{t'}) > 0$ and $t' < t$." (1970, p. 12). Then, he defines the genuine causes as those that are not spurious. An event $B_{t'}$ is a *spurious cause* in sense one of A_t if and only if event $B_{t'}$ is a *prima facie* cause of the A_t and there is an event $C_{t''}$ such that $P(A_t \mid B_{t'} C_{t''}) = P(A_t \mid C_{t''})$ and $P(A_t \mid B_{t'} C_{t''}) \geq P(A_t \mid B_{t'})$, where $P(B_{t'} C_{t''}) > 0$ and $t'' < t'$. (1970, p. 23).

The former notions allow for deterministic cases, where the value of probability assigned to statements as $P(A_t \mid B_{t'})$ equals the unity and, consequently, any other different event –A has probability zero. This conforms with the following Suppes´ definition: "An event $B_{t'}$ is a sufficient (or determinate) cause of A_t if and only if $B_{t'}$ is a prima facie cause of A_t and $P(A_t \mid B_{t'}) = 1$." (1970, p. 34). I consider deterministic cases uninteresting for a conception of probabilistic causality. From a deterministic Laplaceana view of the physical word, probability statements are the expression of our ignorance of the real causes, and they lack of any objective reference to the world itself. Thus probabilities have not an objective character and it is worthless to apply them to indeterministic processes.

The philosophical relevant cases are those where the causes are not sufficient or determinate, where $P(A_t | B_{t'}) < 1$. This accord with Suppes´ remark about the application of his probabilistic notions on causality: "There are at least three different kinds of conceptual frameworks within which it seems appropriate to make causal claims. […] One conceptual framework is that provided by a particular scientific theory…" (1970, p. 13), and elsewhere: "… when one analyzes the formal character of a theory that is formulated as a class of stochastic processes." (1984, p. 52).

Furthermore, the authors referred do not take into account that the laws of the scientific theories, in less or more extent, are idealized statements, statements that are formulated under a variety of unrealistic suppositions and, hence, are satisfied only in ideal systems —such as frictionless pendulum, material bodies as masses concentrated at extensionless points, inertial bodies free of acceleration, rigid bodies, perfectly elastic spheres, potential wells and harmonic oscillators systems, which do not exist in nature—, simply they overlook this issue. In order to apply the idealized laws of science to the world it become necessary first to 'de-idealize' them, to eliminate the unrealistic suppositions by means of Leszek Nowak´s method of concretization (1992), and Ernan McMullin´s procedure of de-idealization (1985).

The main aim of this paper is to provide some probabilistic notions on indeterministic causality or, alternatively, notions on probabilistic causality proposed to be applies to the nomic statements which intent to give account of the indeterministic processes in the domain of a scientific theory. The nomic or likelaw statements involved are generally, in more or less extent, idealized statements. Therefore the statements to study are, in first instance, of the general form: $P(S(x) | d(x), R(x), U(x))$, where x stand for a system, $S(x)$ for a class of final states of x, $d(x)$ for certain initial state of x, $R(x)$ for some realistic physical conditions that make possible the elements of $S(x)$, and $U(x)$ for some unrealistic suppositions. P is thus a probability distribution over $S(x)$ conditional to $d(x)$ given $R(x)$ and $U(x)$. I try to show how the probability distribution over $S(x)$ changes according to the nomic statement in question is de-idealize by means of the addition of causally relevant factors. Besides, in the course, I attempt to contrast the ideas embraced here with some of the notions of Paul Humphreys´ ontic conceptions of causality and explanation, which are contrary to the epistemic view adopted here about those subjects.

Idealized Laws

Stochastic processes

Let us begin with some ontological notions. A *process* is a transformation that a system undergoes from an initial state to a final state. An *indeterministic process* is a process in which, given an initial state, it is physically possible that two, several or many final states occur, which can be correlated, without determine any one. A *stochastic process* is an indeterministic process in which the two or many final states exclude each other. Furthermore, let it assume that the systems within the domain of application of a theory are described or depicted by a set of concepts which refers to magnitudes or qualitative features, which I will call here 'factors'. At the same time, the laws or nomic statements of the theory are formulated in terms of such factors. We can say that for each system of certain specific kind there is a special law or a nomic statement of the theory that prescribe the possible transformations that the system could undergo.

The issues to discuss forward are, on the one hand, whether the factors that occur in the formulation of a law, nomic statement, or principle of a theory are realistic or idealized factors and, on the other hand, whether such factors are causal or not. If a given law is an idealized law, without any realistic factor in its formulation, then it is inapplicable as such to any system, and one is unable to consider if its factors play a causal role, or if the law is a causal law, or if a given process in its domain is a causal process, and so on. In this way, it becomes necessary, in the first place, to de-idealize the laws in order to inquire about causal matters.

Generally, the laws or principles of science are formulated incompletely, as Nowak point out, in terms of some realistic or feasible factors and presupposing some idealized or abstracted factors. As we will see, the de-idealization and concretization of a nomic statement by means of inclusion of the factors previously omitted *changes* the probability distribution, assigning new transformation probabilities to the system from a given initial state to possible final states. In fact, as we will see later with an example, the whole formulae change, even its mathematical form.

Nowak´s method of concretization

The notions of idealization and abstraction, and the inverse notions of de-idealization and concretization, are explained in rough terms as follows.

Nowak distinguishes, among several notions of idealization, which he calls paradigms of idealization, the following two: "The *neo-Lebnizian paradigm*. Idealization is a deliberate falsification which never attempts to be more than truthlike. An idealizational statement is a special type of a counterfactual which has to do with what goes on at possible worlds given by the antecedent of the statement.", and the *neo-Hegelian paradigm*, which is the concept of idealization that he endorses: "[…] it refers to Hegel´s idea that idealization ("abstraction") consists in focusing on what is essential in a phenomena and in separating the essence from the appearance of the phenomenon." (1992, pp. 9-10) The former concept refers to what is mostly considered as a proper idealization under the name of Galilean idealization. For example, Ernan McMullin says that: "The term 'idealization' itself is a rather loose one. I shall take it to signify a deliberate simplifying of something complicated (a situation, a concept, etc.) with a view to achieving at least at a partial understanding of that thing. It may involve a distortion of the original or it can simply mean a leaving on the remaining one." (1985, p. 248).

The second concept of idealization, the neo-Hegelian *abstraction*, devoid of its metaphysical expression, designs the procedure of selection of some relevant factors or parameters in order to, let us say, explain a kind of physical process because one can consider them as either causal, influencing factors or as other explanatory reason. Indeed, it refers to the Aristotelian concept of abstraction, to which Nancy Cartwright wrote: "[…] I should like to reserve the word 'abstraction' to pick out a more Aristotelian notion, where 'abstraction' means 'taking away' or 'subtraction'. For Aristotle, we begin with a concrete particular complete with all its properties. We then strip away —in our imagination— all that is irrelevant to the concerns of the moment to focus on some single property or set of properties, 'as if they were separate'." (1989, p. 197).

Nowak draws a distinction between both concepts: "Roughly, abstraction consists in a passage from properties *AB* to *A*, idealization consists in a passage from *AB* to *A-B*." (2000, p. 8). In both cases, the property A has been selected but in the passage of abstraction the property B is simply subtracted, whereas in the passage of idealization the property B is negated or, more likely, distorted. Thus, abstraction embraces two tasks: pick out some properties and omit other properties. In contrast, in an idealizational passage, a property is indeed distorted, so the idealization of an object or system does not consist in just picking out some properties but also in simplifying, deliberately or not, by guessing a distortion in the object or system.

For sake of clarity let us say that in both idealization and in abstraction some *unrealistic suppositions* are involved. In the former the suppositions are rather *counterfactual* assumptions whereas in the latter the suppositions are *counter-actual* assumptions. This distinction between two types of unrealistic suppositions corresponds roughly to Nowak distinction between the neo-Leibnizian and neo-Hegelian paradigms.

According to Nowak, the properties subtracted or negated can generate counter-actual statements by means of the introduction of idealizing conditions of the form $p(x) = 0$. This procedure can render law-like statements which Nowak calls idealizational: "An idealizational statement is a conditional possessing an idealizational condition in its antecedent" (1992, p. 11). The procedure of *concretization*, in Nowak´s sense, consists of removing that condition and replacing it with its realistic negation, and introducing a correction in the formulae (consequent) of the statement (see Nowak 1992). In this manner, the concretization procedure leads to a more realistic statement than the initial idealizational statement.

More explicitly, according to Nowak, in order to formulate a law which allows us to determinate the value of some magnitude F, a researcher selects some factors H which he considers principal for the process or phenomenon under consideration and makes an idealizational hypothesis by postulating a functional relationship f between the magnitude F and the principal factors H, which is the formulae occurring in the consequent of the law-like statement. Some other secondary factors p, with values equal to 0, are attached into the antecedent of that statement by the researcher. The result is an idealizational and counter-actual law of the form:

> If $G(x)$ & $p_1(\mathrm{x}) = 0$ &…& $p_k(\mathrm{x}) = 0$ then $F(x) = f_k(H_1(x),\ldots, H_n(x))$, where $G(x)$ stands for a realistic and actual condition. (cfr. Nowak, 2000, p. 9).

Basically, Nowak thought of a sequence of statements which leads to a final factual statement via the procedure of concretization, this is to say, by means of elimination, step by step from 1 to k, of the idealizing conditions in the antecedent, restoring its realistic versions, and consequently, introducing a modification in the functional formulae in the consequent. Ideally this procedure of de-idealization of a law-like statement has as a final stage a statement of the form:

> If $G(x)$ & $p_1(\mathrm{x}) \neq 0$ &…& $p_k(x) \neq 0$ then $F(x) = f_0(H_1(x),\ldots, H_n(x), p_k(x),\ldots, p_1(x))$, which lack of any idealizing conditions and is a factual statement (Nowak, 2000, pp. 9-10).

Also, Nowak adds an approximation procedure. He initiates with this right remark: “Normally, however, final concretization is not met in science. Normally, after introducing some corrections the procedure of approximation is being applied. That is, all idealizing conditions are removed at once and their joint influence is assessed as responsible for the deviations up to certain threshold ε.” (1992, p. 12).

Let us briefly discuss the former notions. As we have remarked, in his notion of an idealizing condition Nowak confuses subtracted and distorted properties. That is, in the formulation of the antecedent of an idealization law, Nowak does not distinguish between an idealizing condition derived from a neo-Leibnizian idealization (a deliberate falsification) and an idealizing condition resulting from a neo-Hegelian abstraction (which separates the essence from the appearance). In other words, he fails to differentiate counterfactual suppositions, distinctive of idealization, and counter-actual suppositions, peculiar of abstraction. Consequently, Nowak mingles a combination of de-idealizing steps and concretization steps. In the following example, he considers the frictionless supposition as an idealizing condition and the inverse procedure as a case of concretization: suppose that a system is a classical body in free fall, then the concretization step would consist in moving from the statement ‘if ff(x) & R(x) = 0 then s(x) = $1/2gt^2$’ to the statement ‘if ff(x) & R(x) = r then s(x) = $1/2gt^2 - r$’, where R stands for the medium resistance (see 2000, p. 8). Perhaps, it would be fair to say that the missing friction factor is just a subtracted feature instead of an idealized feature.

Thus, in the context of the explicit and full formulation of the law-like statements by Nowak, it will be better to say that (i) if the unrealistic supposition in the antecedent is counterfactual (a distortion) then the addition of a correction factor in the consequent is a de-idealizing act, and (ii) if the unrealistic supposition in the antecedent is a counter-actual (a subtraction) then the addition of a correction factor in the consequent is a concretization procedure.

Let us reformulate in a double sense the former Nowak´s ideas. First, we can transform a logical conditional statement into a probabilistic conditional statement in the obvious manner: Simply we convert $A \longrightarrow C$ into $P(C \mid A)$. Second, for simplicity, we consider for a system x three sets (no empty) of suppositions: R(x) for realistic suppositions, C(x) for counterfactual suppositions, and A(x) for counter-actual suppositions, in order to formulate probabilistic idealized law-like statements as $P(S(x) \mid R(x), C(x), A(x))$. Each of the previous sets corresponds to some factors: f_R for realistic factors, f_C for idealized factors and, f_A for abstracted factors, respectively.

It is worth noting that if, by a step of concretization, a counter-actual supposition is eliminated, then a more realistic and specified nomic statement is obtained, a statement of the form: $\mathrm{P}(\mathrm{S}(x) \mid \mathrm{d}(x), f_R(\mathrm{x}), f_C(x) = 0, f_A(x) \neq 0)$, where the probability distribution P *varies* in virtue of the inclusion of the factor f_A previously abstracted. Similarly, if in a further step, an idealized supposition is removed by means of the de-idealization procedure, one obtains a nomic statement less idealized and more specified of the form: $\mathrm{P}(\mathrm{S}(x) \mid \mathrm{d}(x), f_R(\mathrm{x}), f_C(x) \neq 0, f_A(x) \neq 0)$, where again the probability distribution has *changed* in function of the addition of the factor f_C formerly idealized.

In short, until now we have considered three cases. Let s(x) in S(x) be a possible final state of the system x undergoing an indeterministic process from an initial state d(x). Then:

$$\mathrm{P}'(\mathrm{S}(x) = \mathrm{r} \mid \mathrm{d}(x), f_R(\mathrm{x}), f_C(x) = 0, f_A(x) = 0)$$
$$\mathrm{P}'(\mathrm{s}(x) = \mathrm{r}' \mid \mathrm{d}(x), f_R(\mathrm{x}), f_C(x) = 0, f_A(x) \neq 0)$$
$$\mathrm{P}'' (\mathrm{s}(x) = \mathrm{r}'' \mid \mathrm{d}(x), f_R(\mathrm{x}), f_C(x) \neq 0, f_A(x) \neq 0),$$

These three probabilistic statements assign to s(x) different values because the probability distributions have change as a function of the addition of relevant factors earlier omitted. As we will see above, the probability values of every s(x) in S(x) could *increase* or *decrease* in function of the factor included.

For our study, it is worth noting that at the extent one obtain a probabilistic lawlike statement free of some idealizations and abstractions, the corresponding probability values for the final states of the system respond to more realistic and specified conditions in which the indeterministic process in consideration happens. This means that one could obtain objective probability values and, we can say, relatively to the theory to which the lawlike statement belongs, the right or correct values of probability. But that is all we can intend. We cannot aim to obtain the exact values, because in science there are not nomic statements free of all idealization and abstraction, and in every case, a threshold ε corresponding to a range of approximation should be introduced.

Nevertheless, it is clear that at the extent that we are able to de-idealize the probabilistic lawlike statements, we could get better and fuller explanations of indeterministic processes.

A case of application: Hardy-Weinberg´s equilibrium principle

Let us illustrate the former ideas with the case of a principle of population genetics:

> *Suppose that Aa is a pair of Mendelian characters, A being dominant, and that in any given generation the numbers of pure dominants (AA), heterozygotes (Aa), and pure recessives (aa) are as p : 2q : r. Finally, suppose that the numbers are fairly large, so that the mating may be regarded as random, that the sexes are evenly distributed among the three varieties, and that all are equally fertile. A little mathematics [...] is enough to show that in the next generation the numbers will be as* $(p + q)^2 : 2(p + q)(q + r) : (q + r)^2$. (Hardy, 1908, p. 49).

Furthermore, Hardy notes that such proportions are *theoretical* because they rest on several ideal conditions. If the generations are discrete, those proportions remain constant, or better, in equilibrium –stables, said Hardy– indefinitely, and neither a dominant character should show a tendency to spread over a whole population, nor a recessive should tend to die out, at least they were being altered by some external force.

Niles Eldredge takes into account four factors which can produce genetic changes: "G. H. Hardy y W. Weinberg, had established that such allelic frequencies are destined to remain constant (the *Hardy-Weinberg equilibrium*) unless and until disrupted by immigration, mutation [a spontaneous and random change in DNA duplication], natural selection [process of differential reproduction of genes or genotypes, and the results of this process] or non-random- mating behavior." (Eldredge, 1999, p. 125).

There is a consensus among evolutionary biologists that the factors that alters the previous principle are those that violate the following suppositions: 1) Mating is *random*, 2) The alleles (one of two or more alternative expressions of a gene), genes (units of inheritance affecting the characteristics of a trait) and genotypes (the genetic makeup of an individual) show no difference in fitness (measure of the relative success of one genotype compared to other genotypes), that is, *selection* in not in operation at this locus, 3) There is not *gene flow* (the spread of alleles through a population or species as a result of successful interbreeding), that is, there is not migrations of genes from one population into another, 4) *Mutation* is absent or so negligible that the allele copy numbers remain constant, and 5) Populations size is effectively infinite, so there is not *genetic drift* (events wherein some alleles spread in a population as a result of random actions rather than a consequence of natural selection). (see Avers, 1989, p. 254).

Of course, such suppositions are counterfactual or, in the best case, counter-actual. Mutations and natural selections are the fundamental factors of genetic changes and evolution. Their omission represents a high idealization, which are indeed counterfactual. The other three suppositions

–random mating, not genetic flow and not genetic drift− can be considered counter-actual because although they do not actually happen in nature, it is possible that they could happen.

Let p and q be, with $p + q = 1$, the frequencies values of alleles A and a in a given locus, respectively. Then by the formulae $p^2 + 2pq + q^2 = 1$ one can get the proportions of the three genotypes AA, Aa and aa. If, for example, the frequencies of both alleles are equal, one obtain that for the next generation the values of the proportions of the former genotypes are ¼, ½, and ¼, respectively. This is elemental: the basic form of the HWP.

Now, we can reformulate the HWP as a nomic probabilistic statement, in Nowak´s style −where f_R stand for the frequencies values of alleles A and a, MA mating system, M for migration, μ for mutation, and S for selection−, in the following manner:

$$(p^2AA + 2pqAa + q^2aa = 1 \mid f_R, \mathrm{MA} = 0, \mathrm{M} = 0, \mu = 0, \mathrm{S} = 0)$$

A step of concretization of this formula removing the unrealistic suppositions of random system of mating, change the probability distribution on the three genotypes involved. Suppose an assortative mating where similar organisms tend to choose each other as mates. Then the HWP is modified as:

$$(p^2 + pq/2)AA + pqAa + (q^2 + pq/2)aa = 1$$

Thus, given that the frequencies values of alleles are equal, the probability distribution varies, and one obtains the values 3/8, 1/4, and 3/8 for the three genotypes, respectively (see Sober, 2000, pp. 3-4).

The probabilistic formulation, for example, for the heterozygote genotype is:

$(\mathrm{P}(Aa) = 1/4 \mid \mathrm{f}(A) = \mathrm{f}(a) = 1/2, \mathrm{AS}, \mathrm{M} = 0, \mu = 0, \mathrm{s} = 0)$,where AM means assortative mating.

Note that these mating system increases the probability of both homozygotes (individuals carrying identical alleles for a trait) genotypes while decrease the probability of the heterozygote (individuals carrying two different alleles for the same trait) genotype.

A step of de-idealization eliminating in this case the counterfactual suppositions of selection factors also missing, modifies the basic version of HWP. In order to do that we must introduce a selection coefficient (the proportional reduction of the contribution of gametes in comparison to the standard genotype) as Elizabeth Lloyd does (1984, p. 247). She presents a model to predict (in an ideal system) the probabilities of the three genotypes after selection, in the case of simple dominance when the fitness of genotypes

AA and *Aa* equals 1 and the fitness of *aa* is (1 – s). Lloyd use the following formulae:

$p^2AA + 2pqAa + (1 - \mathrm{s})q^2aa = 1 - \mathrm{s}q^2$

Applying that formulae, the probability of the recessive genotype decrease:

$(\mathrm{P}(aa) = sq^2 \mid \mathrm{f}(a) = r < 0.5, \mathrm{MS} = 0, \mathrm{M} = 0, \mu = 0, \mathrm{S} \neq 0)$

Again, as we can see, what is modified with the introduction of a factor previously idealized is the distribution of probability.

Finally, let us remove the contrafactual suppositions which omit mutations. Suppose that in a given locus with two alleles *A* and *a*, a spontaneous mutation (a change in a DNA nucleoids sequence) takes place, and generate a new allele α: In a single generation certain amount of allele A converts to allele α. This refers to a mutation per gene per generation with a rate μ which varies in function of the variation of the amount of allele *A*. Thus, in an initial generation G_1 a percentage μ of allele *A*, μ_A, convert to the new allele α, with a value *r* in such a way that we obtain $p_1A = pA - r$ y $\alpha = r$. Let the mutation rate remain constant in *n* discrete generations. In a *k* generation, with $1 < k \leq n$, we have:

$p_k^2 + q_k^2 + r_k^2 + 2p_kq_{k+} 2p_kr_k + 2q_kr_k = 1$, where $p_k = p_{k\text{-}1} - \mu_A$, $q_k = q_{k\text{-}1}$ y $r_k = r_{k\text{-}1} + \mu_A$.

The inclusion of the new mutant allele modified the simple form of the HWP. This means that in the corresponding probabilistic formulation the null value of mutation is eliminated and the equality is replaced by the formed equation which contain the *r* value for the α allele frequency. In this case, the class S(*x*) of final state of the system *x* has also changed.

In the case of the Hardy-Weinberg principle we have seen that its formulation requires some realistic conditions −such as populations of diploids (full normal number of characteristic somatic cell chromosomes) organisms with sexual reproduction, the sexes are evenly distributed among the three varieties, and all are equally fertile− and that its application needs de-idealize its original formulation via the elimination of some unrealistic suppositions, the addition of some corresponding relevant factor, and a reformulation of its basis equation. In each and every case of this sort the probability distribution changes.

One can realize that the genotypes and, consequently, the respective phenotypes (the realized expressions of the genotypes and of environmental influence) of diploids organisms with sexual reproduction are the results of *multiple* and *diverse* relevant factors such as mating system, natural selection, mutation, and migration. One could construct several models according to those of the former factor −and other like an infertility rate− one takes into account. Those models could be mathematically complex, and each one provides to the genotypes involved different values of probability. One could think that the *complete* model, which incorporate all the relevant factors, give us the correct values of probability of the genotypes. However this is relative to the present theory of biological evolution. We cannot assume that the contemporary theory of evolution of species, including population genetics, is the complete theory of the living world. All that we can ask is whether in a given model, the probability distribution is correct according with our present biological knowledge. But forget about the *true* values!

Casual processes

Until now, I have avoided deliberately to considerate whether the previous factors are causal or not. In relation to the generation of genotypes −and, thus, phenotypes− the factors involved are mutations during the processes of replication and recombination of genes containing inside the parent gametes (reproductive cells carrying only half of the complement of the organisms' chromosomes) On the one hand, mutations, as genetic processes that can generate novel genotypes and innovative variations, are random in nature and occur spontaneously, without a cause. On the other hand, recombination is a process where the parent's genes are combined at random giving place to novel zygotes. The importance of this is fundamental because it signifies that chance plays a crucial role in evolution: the production of genetic variation, over which natural selection works. We can verify in the pertinent literature that the remainder kinds of processes —natural selection, mating system, migration, and others— are considered in general by the evolutionary biologists as causal processes that may produce evolutionary changes (see Avers 1989, Ayala 2012, Eldredge 1998, Lewontin *et al* 1999, Gould 2002, and Mayr 1991).

My general view on this issue consist in, roughly, that deeming a factor, variable or condition as causal is a matter of the whole conceptual framework which one adopt or of the global scientific theory one apply. As Suppes points out: "It is important to emphasize that the determination of a causal relationship between events or kinds of events is always relative to some conceptual framework." (1970, p. 13). This entails that, in the field of science, anyone is able to say that there is a causal process of certain kind in nature, independently of any theoretic framework. This thesis, which for someone could seem a truism because we cannot say how the world is in an absolute sense, stand against some ontic theories of causality, in opposition to epistemic theories.

In any case, we can advance some causal notions in order to elucidate what probabilistic causes could be in the previous example from population genetics. First of all, we should assume that the realistic factors make possible each of the final states in S(x) of a given system, this is to say, for any s(x) in S(x), $P(s(x) \mid d(x), R(x)) > 0$. In the case of the HWP, S(x) is the set of the three genotypes {*AA*, *Aa*, *aa*}, d(x) is a given probability values for the alleles *A* and *a*, and R(x) is a set of suppositions about a population such as the organisms are diploids with sexual reproduction, and some else more realistic and specific conditions. In this sense, we can consider the realistic factors as *actual probabilistic causes* of every element in S(x).

Moreover, we can deem that the de-idealized and concretized factors could be causal factors in relation to the final states just in case that for all s(x) in S(x):

$$P(s(x) \mid d(x), R(x)) \neq P(s(x) \mid d(x), R(x), f(x)),$$

where f(x) is the additional factor. In this case we can simply say that f(x) is *causally relevant* with respect to s(x). As we have seen in our example, the addition of a factor changes the probability distribution and, given that the process under question is an indeterministic process, the new probability function could increase or decrease the values of the different final states in S(x). We will say simply that f(x) is in the first case a *positive probabilistic cause* of s(x) and that f(x) is in the second case a *negative probabilistic cause* of s(x). We have seen that one and the same factor, assorting mating, is a positive cause of the homozygote genotypes and a negative cause of the heterozygote genotype. The probabilistic character of these two sorts of causes resides precisely in that they change the respective probabilities, whether increase or decrease its values.

As our example also show, the attachment of a previous omitted factor into the lawlike statement can even change the domain of the probability function. That is the case of the mutation which introduces a new allele in a locus generating novel genotype. Finally, in all cases, the nomic or lawlike statement involved is reformulated because the inclusion of a causal factor changes the probability distribution itself. This suggest a close relationship between causes and probabilities: if we consider, as I do, the probability statements as expression of the degree of objective chance in indeterministic processes, we can say that there is an interplay between causes and chance.

All the prior has the consequence that in order to be able to make causal claims about the processes within the domain of application of a scientific theory, one must first to de-idealize the laws of the theory, so as to obtain more realistic and specific lawlike statements. If, according to our theoretical framework, included our philosophical conception of how the world is, we deem the factors incorporated in a nomic statement as causal factors, then we can think of them as factors that change the probabilities of the possible effects −that is, as causally relevant factors because they can increase or decrease the probabilities of its effects. It seems right to say in those cases that the processes are *causally probabilistic.*

The fact that the causal factors do not determine a unique effect with probability equal to the unity, but rather that they allows us to assign only probabilities values between 0 and 1 to the possible effects of an indeterministic process means precisely that such factors are indeterministic causes of its aleatory effects. Whether a given cause increase or decrease the probability of a certain effect, that cause is a *probabilistic cause* of that effect. It becomes unnecessary that a certain cause rise the probability of an effect in order to be a probabilistic cause of that effect. It is required, first of all, as a minimal necessary condition that there are some factors that make possible the effects, in the sense that the corresponding conditional probabilities have a value greater than zero. When we are dealing with a genuine indeterministic process –a process which its possible effects have objective probabilities− we must, of course, consider its entire domain −i. e., the set of all its possible effects− in order to define a probability distribution. It is a mistake, among most authors, to take into account only one effect of a process and analyze its possible causes, whether positive or negative causes.

The value of probabilistic notions on causality, such as the previous notions of positive and negative probabilistic causes, reside in part precisely in its application to processes which effects have not sufficient causes, effects that are aleatory such as the proportions of homozygotes and heterozygotes genotypes given a certain mating system, and the formation of an triton atom plus a proton given an interaction between two deuterons.

Causal vs. probabilistic explanations

Humphreys has elaborated a realistic conception of probabilistic causality from an ontic view of causality and explanation, as opposed to epistemic or modal views. According to him, what explains a given event or phenomenon are other events or phenomena, its causes. A scientific explanation consist, thus, in a specification of the causes of the phenomenon to be explained, causes which ordinarily are multiple. Generally, the explanations are not complete because our knowledge of the causes of the phenomena that occur in the world is incomplete. However, this incompleteness of our causal knowledge does not preclude causal claims to be true. (see 1989, p. 101).

In order to a kind of events to be a cause of another kind of events it is necessary that the former exert invariably an influence to the latter. The invariable influences may be for or against to a certain kind of result or effect. Therefore there are, according to Humphreys, two kinds of causes, that he characterize as follow: "Let us, generalizing our principle, preliminarily characterize a factor *X* as a *contributing cause* of *Y* is and only if the occurrence of *X* results in an increased chance of *Y*, and characterize a factor *Z* as a *counteracting cause* of *Y* if and only if the occurrence of Z results in a decreased chance of *Y*." (1989, p. 16). These two kinds of probabilistic causes can be applied to the indeterministic systems as well to deterministic cases where the effects have sufficient causes (see 1989, p. 101). Many events are the result of both contributing and counteracting causes. In such cases the manner to answer to the question "Why X happen?" is "*X* because *Y* despite Z", where *X* is the explanandum, *Y* is a contributing cause, and *Z* is a counteracting cause.

Humphreys intends that his theory of causal explanation has applications in several sciences: social, medical and physical science. However, he admits the limits of his theory since it is unable to explain phenomena like the disintegration of uranium atoms. The causes, only the causes and all the causes explain the phenomena in the world, according to Humphreys, and chance do not explain anything (1989, pp. 112 and 118). As disintegration of uranium atoms occurs just by chance, that kind of phenomena has not explanation within his theory.

From a causal realism, Humphreys maintain that only the causes, whether deterministic or probabilistic, are able to explain the events that happen in the world. Moreover, he argues that the probabilistic explanations, which consist in specifying the correct value of probability of the explanandum, are inappropriate because probability values lack of explanatory power: "This fact that probability values are epiphenomena of complete causal explanations indicates that those values have themselves no explanatory power, because after all the causal factors have been cited, all that is left is a value of sheer chance, and chance alone explains nothing." (1989, p. 113).

Salmon decline the condition of high probability of the explanandum statement of Hempel´s inductive-statistical model. The problem with this condition is obvious: it leaves without explanation abundant sorts of atomic processes which have low probabilities. Salmon argue that "If one and the same probability distribution [...] provides explanations of two separate events, both explanations are equally valuable." (1984, p. 89). As we can see, Humphreys rejects this thesis about probabilistic explanation because for him only the causes can provide explanations: the probabilistic nomic statements derived from a scientific theory lack of explanatory power –no matter its values– because just the causes give explanations of the phenomena which happen in the world.

In quantum mechanics, the theory provides probability values to a diversity of kinds of processes like fission, fusion, disintegration, annihilation, scattering and quantum jumps. Indeed, it is hard to think how we could explain anything in the quantum domain if one rejects, as Humphreys does, the probabilistic nomic statements of quantum theory as means to explain the quantum processes just on the ground that only causes have explanatory power. Some of the previous processes have a causal constituent. The interactions between two particles in fissions and fusions can be considered, in terms of Salmon´s theory of causality (1998), as causal interactions, in which both particles involved are transformed. In the case of disintegration and quantum jumps there are not such interactions and they occur spontaneously at random. However, there are some backward physical conditions −in the disintegration cases the instability of the radioactive elements−, which make possible those processes. The abandon of Hempel´s models of explanation do not entail to leave behind the paramount role that scientific laws have in explaining what happens in the world.

I think the separation that Humphreys make between causes and chance is just an abstraction, an abstraction that if one try to apply to some scientific field, such as population genetics and quantum mechanics, do not make much sense. The main idea of the theories of probabilistic causality is precisely to think of events that happen in the world without sufficient causes, but rather with probabilistic causes, i. e., causes that produce its several effects only with some probabilities.

The fusion of the notions of causes and chance in some proposed concepts of probabilistic causality has been the key in the theories of probabilistic explanation. The basic idea is simply that some events produce other events probabilistically, as opposed to deterministically, and thus we are able to explain the latter in terms of the former. To show that an event is *probable* in virtue of the occurrence of some other event is part of the explanation of the former in terms of the latter. In this order of ideas, it is required that the events to be explained have a positive probabilistic value, high or low. We cannot expect to obtain the exact value of probability of the explananda events because this aim assumes that we are able to de-idealize totally the laws of science under the presupposition that our theories are complete. This could be too complicated and implausible in many cases as our example of the principle of equilibrium of Hardy-Weinberg suggest.

Let us return very briefly to the Humphreys´ thesis about the incompleteness of causal explanation. He says that: “If all the causal factors identified in the explanation are genuine causes of the explanation phenomenon, then that explanation is true. Whereas it is necessary to insist on the truth of an explanation, it is unwise insist upon its completeness, for to do so would rule out almost every explanation ever put forward of a natural phenomenon.” (1989, p. 112) So Humphreys´ maxima turns into “the causes, only the causes, yet not all the causes”. He is right not only for practical matters about the unfeasibility to obtain all the causes of a phenomenon in a complex and messy world, but for the complicatedness of de-idealizing all the factors involved in the law-like statements required to get a complete explanation.

Besides, the truth of a causal explanation of a singular event or phenomenon lies on that the causes cited in the explanation are genuine causes. How one can determinate whether a factor intervening in a process is a genuine cause or not? With respect to this, Humphreys demands that causal influences satisfy an invariance condition. Such invariances need to be expressed by general statements, which for him are causal laws. With respect to this he says:

> *Aleatory explanation [explanation of aleatory phenomena] still requires laws to ground explanations, but reference to these laws does not appear directly in the explanations themselves, and they are not covering laws. The role that causal laws play here is a part of the truth conditions for the explanatory statement. In order for something to be a cause, it must invariantly produce its effect, and, hence there is always a universal law connecting cause and effect. The existence of such a law is therefore required for something truly to be a cause, but the law need be referred to only if it is questioned whether the explanatory material is true* (1987, p. 114)

But this last thesis which grants to the causal laws a paramount role on explanation in detriment of theoretical laws drive in the inverse direction. Let me ask: What are the causal laws that connect invariantly the causes and its effects in quantum processes, which are stochastic processes, such as fusion and fission? For example, in the case of a fusion of two deuterons, ${}^{2}_{1}d + {}^{2}_{1}d$, it is physically possible for a transformation to occur by either of two exclusive and exhaustive routes: the formation of a nucleus ${}^{3}_{2}\mathrm{He}$, a light isotope of helium, plus a neutron, or the formation of a triton plus a proton.

Both results are about equally probable, according to quantum theory. What are the causal laws applying to this indeterministic process? The invariances required by Humphreys in this kind of cases between causes and effects can be just of probabilistic character, expressed by statements assigning a value to each of the two possible routes. Thus, it seems that we cannot be dispensed with probabilistic statements in order to explain stochastic processes, even to express that there is an invariable causal influence between two sorts of events which one thinks of as causes and effects. From quantum theory one can derive probabilistic nomic statements which assign probabilities values to the aleatory effects in all of the prior processes, *and nothing else*.

Conclusions

In order to advance on the issue of probabilistic causality, the appropriate probabilistic statements that we must analyze are of the form P(S(*x*)| R(*x*), F(*x*)), where *x* stand for a system in certain initial state (physical, biological or something else), R(*x*) is a set of realistic suppositions, F(*x*) is a class (possibly incomplete) of relevant factors previously omitted but which have been de-idealized or concretized and integrated to the formulation of the lawlike statement or model, and lastly, S(*x*) is the set of possible final states of the system *x*, given certain initial state, relatively to a theory T.

It is of crucial importance to realize that if some factor in F(*x*) is modified or some neglected factor is incorporated to F(*x*), the entire probability function P changes, and new values are possibly assigned to all s(*x*) in S(*x*). This simple result have no place in the traditional treatments which (i) disregarded the idealized character of scientific laws, and (ii) generally analyzed statements of the form P(A | C, Z) > P(A | Z), which are not appropriate to indeterministic processes since they do not include an event A´ alternative to A, and possibly incompatible with it, that could occur under the same conditions C and Z.

The significance of probabilistic notions on causality, such as the prior notions of positive and negative probabilistic causes, reside, in part, in its application to stochastic processes −processes which have not sufficient causes−, and thereby which effects are aleatory; effects like the proportion of the heterozygote genotype given certain mating system and the formation of a triton atom plus a proton given an interaction between two deuterons particles. By means of this sort of notions it could be plausible to construct models which give an account of some kind of indeterministic processes in terms of causes which produce its aleatory effects probabilistically.

Nevertheless, the probabilistic notions on causality, like those of Humphreys, are not sufficient to elaborate a general conception of explanation of indeterministic processes because some genuine stochastic, or aleatory, processes occur just by chance –processes such as genetic mutations and quantum jumps–, and therefore they cannot be explained even in terms of probabilistic causes. Thus, if one rejects the probabilistic explanations –the explanations of indeterministic processes in virtue of its probability values– one leave those kinds of processes without explanation at all.

As I have already said, one considers a given process as a causal process relatively to a general conceptual framework or to a global theoretic framework. As the other scientific claims about how the world is, the causal claims are provided from a given conceptual framework of a theory. Some philosophers have proposed what they call an ontic view on causality and explanation which are intended to be independent of the scientific theories. In this sense, Salmon, Humphreys and others who have proposed ontic theories of causality, seem think that one is able to say whether a given process is causal or not in an absolute manner, in a way which is no dependent of any scientific theory, but rather simply based on their own theories. I think this misunderstands the whole question about causality.

We make causal claims assuming a philosophical or extratheoretic conception of the world which constitute the domain or application of the theory involved. We cannot maintain based on formulations of scientific laws that the processes involved, processes to which we apply these laws, are causal processes, because in general such laws are mathematical equations. Again, one can hold that a kind of process is causal from a philosophical view of how the world is, in a way relative to the theory studying the process in question. To hold that a causal claim is true involves that the theory from which one make such claim is true. Thus, is highly controversial to maintain that one can make true causal claims, from an ontic conception of causality, exempt from epistemic compromises.

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