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WHAT IS CHANCE?

MARIO BUNGE

THE problems of the existence and nature of chance have been sharply discussed ever since the dawn of philosophy. Nevertheless, few philosophers have dealt with this question in a systematic or detailed way. The overwhelming majority have treated chance in a marginal and negative manner, that is as related to its opposite, necessity. Nearly all of them have proceeded dogmatically; a priori taking sides for or against the objective existence of chance.

The old controversy has recently spread into the field of science. The analysis of contingency has not, however, made noteworthy progress. There are now more examples of chance, but not a deeper insight into its nature. The question appears in three of the major contemporary scientific controversies: genetics, quantum theory and, of course, in that branch of science which most people suppose to be devoted to chance in general, the theory of probability. An inquiry into chance is therefore justified.

I. THE CLASSICAL APPROACH

For all the widespread discussion of chance in modern science, and in spite of the fact that probability calculus is taken to be the science of chance, a satisfactory or even an exhaustive discussion of the nature of chance will not be found in treatises on probability, and least of all in books of statistics, which are concerned with the measurement and analysis of contingent phenomena. Aside from the subject's intrinsic difficulty, the main reason for this situation is that the problem of chance is a fundamental, a philosophical one, and the positivism that tinges bourgeois science makes the latter disdain the examination of philosophical problems. Yet such ques-

tions, dismissed curtly as pseudo-problems, re-enter unavowed.

Typical of this agnostic attitude is the categorical refusal of Bertrand, one of the most eminent authors on probability, to define chance. In 1907 he wrote, "It is possible to reason without error on a subject which is vaguely defined. Is it necessary to take the chemist away from his retorts to cross-examine him on the nature of matter?"¹ The alleged empiricist Borel, the most eminent and prolific of modern writers on probability, does not avoid this positivistic flatness. In all of a recent book devoted to chance, he just manages to say that "The characteristic of the phenomena which we call fortuitous or due to chance is that they depend on causes too complex to be all known and studied."²

It is difficult to make so many errors in a single sentence. Actually, a) complexity is not characteristic of *all* accidental events, as we see in the case of elementary atomic processes, though it characterizes most hitherto known chance events; b) Borel's "definition," which is negative and purely epistemological, implicitly supposes that chance *never* has objective reality, and as such the progress of knowledge must gradually eliminate it—a rationalistic assumption contradicted by the history of the science of the last century; c) J. S. Mill had already pointed out in 1843, that "It is incorrect to say that any phenomenon is *produced by chance*; but we must say that two or more phenomena are *conjoined by chance*."³ Mill had in mind only one type of contingent events, those constituted by the crossing of two or more causal lines. Nevertheless, his criticism is right: the phrase "due to chance" only has a meaning if one grants that chance is an active force, as for example, in the belief in Tyché, the goddess of chance.

In Aristotle's *Physics* (which is less metaphysical than Borel's empiricism) may be found more exact and sagacious remarks on chance and fortune. Cournot (1801-1877), had courage enough to approach the question directly and in detail. He takes up, develops and modifies the Aristotelian thesis, maintaining the objective reality

1 J. Bertrand, *Calcul des probabilités*, 2me. éd. (Paris, 1907), p. vi.

2 E. Borel, *Le hasard* (Paris, 1948), p. 5.

3 J. S. Mill, *A System of Logic*, Bk. III, ch. XVII, § 2.

of chance and noting that contingency and necessity do not exclude each other. His definition of chance by the *combination* or the *encounter* of other events pertaining to mutually *independent* series are those which we name *fortuitous* events or result of chance."⁴

Even if one should succeed in reaching the Laplacian ideal of the reduction of all natural laws to a small number of them, chance would subsist, Cournot argues, since there always would be crossings of independent series. That is to say, chance does not arise exclusively from our ignorance, nor does it decrease as ignorance decreases. With these theses, Cournot penetrated much more deeply into chance than his mechanistic forerunners and his eclectic successors. But he is still limited, and lacks dialectics completely. Chance and necessity are to him poles of an external relationship between thoroughly *independent* causal lines, and not a form of their reciprocal action. Moreover, for Cournot there can be chance only as long as *more than one* line of development is taken into consideration. He does not see the fortuitous breaking of a single line of self-movement. In short, Cournot wished to conciliate, not to unite chance and necessity, indeterminism and determinism.

Poincaré (1854-1912), who by chance was put in charge of a course on probability, is perhaps the only author in this century who was courageous enough to attempt to probe into the nature of chance. As a result of the examination of several examples, he distinguishes two characteristics of contingency. These are: a) the complexity of causes, which, nevertheless, is not always in the realm of chance; b) "for small differences in the causes, great differences in the effect." While acknowledging that chance is something more than "the measure of our ignorance," he does not venture to define it. However, Poincaré goes so far as to criticize Laplacian determinism. He points out that even when we know the law we do not eliminate chance, since small (and unavoidable) terrors in the knowledge of the initial conditions may produce a great incertitude in the knowledge of the final state. Thus "Prediction becomes impossible and we have the fortuitous phenomenon."⁵

4 A. A. Cournot, *Exposition de la Théorie des chances et des probabilités* (Paris, 1843), §40.

5 H. Poincaré, *Calcul des probabilités*, 2me. éd. (Paris, 1912), p. 5.

But Poincaré is illogical. Although he rightly observes that in order to be able to state a problem in terms of probabilities we need a minimum of data, and not a total ignorance, he clings to the Laplacian thesis that "A probability problem arises only as a result of our ignorance."⁶ However, a little earlier he had maintained that probability questions are consistent with a complete knowledge of the law and the circumstances under which it is fulfilled. Poincaré's instance is conclusive and worthy of his wit: an omniscient physician who knew when the clients of an insurance company are to die, would remove the director's ignorance, but this knowledge would not have the slightest effect upon the company's dividends.⁷ The latter were calculated, in fact, upon the basis of a statistical knowledge of the insured persons' life-spans, and the law of large numbers, which made this calculation possible, holds for any population of random elements or accidental events—and this independently of the fact that a more detailed knowledge should have converted them, for us, into necessary facts.

Although Cournot and Poincaré, the mathematicians who have dealt with the nature of chance in most detail, have answered many questions, they evoke even more doubts. Cournot told us—what the Stoic Chrysippus knew a long time ago—that accidents are intersections of two or more causal lines. Poincaré gave precision to the saying "For little causes, great effects." The former maintained that contingency would subsist for the omniscient spirit imagined by Laplace, because chance is not only in our mind but also in things. The latter hesitated between the possibility of reaching the limit of certain knowledge, which would absorb all contingency into absolute determination, and the coexistence and compatibility of certainty with probability propositions.

As we stated at the beginning, it is fruitless to seek exhaustive or even consistent elucidations of general questions in the classics of bourgeois science. Since the specialists in the so-called "science of chance" have been unwilling or unable to carry out a satisfactory ontological as well as epistemological analysis of chance, let us at-

⁶ *Op. cit.*, p. 30 f.

⁷ *Ibid.*, p. 3 f.

tempt an independent analysis, first glancing at the status of the problem prior to the appearance of Marxism.

II. THE METAPHYSICAL DILEMMA: DETERMINISM OR INDETERMINISM

The first problem that arises in the consideration of chance is whether it exists objectively or not, whether it is or is not an entirely subjective category doomed to disappear with the progress of knowledge. In traditional metaphysics (as Hegel understood the term), the answer to this question is conditional upon the acceptance or rejection of determinism. If everything is strictly predetermined, chance does not exist objectively and is but an aspect of our ignorance; in the contrary case, it is necessity, not chance, that is only apparent.

In both forms of the metaphysical method necessity and chance are mutually exclusive categories. An event is either necessary or accidental. If it is necessary, it cannot be composed of accidents nor can it originate an accident save through the external crossing of causal lines. If it is fortuitous, it cannot have been caused by nor can it be subjected to any law.

The metaphysical system which accepts classical determinism excludes contingency from the sphere of reality. It accepts *uncertainty*, as a temporary degree of knowledge (*i.e.*, it considers chance as an epistemological category), but not accident *in re*, as an ontological object. If the determinist is religious, he will apply to his supreme deity what Pindar attributed to the Pythian Apollo: he "knows the end supreme of all things, and all the ways that lead thereto; the number of the leaves that the earth putteth forth in the spring; the number of the sands that in the sea and the rivers are driven before the waves and the rushing winds; that which is to be and whence it is to come."⁸ His emblem will be Bossuet's famous saying: "What is chance in relation to men, is design in relation to God."

Should the determinist not be religious, he will maintain a

⁸ Quoted by B. Farrington, *Science and Politics in the Ancient World* (London, 1939), p. 79.

mechanical teleology instead of a theological one and Laplace's *Esprit Universel* in the place of its cousin God. He may repeat the words uttered by a character of Anatole France:

Call a wretch to account for his acts! . . . but when the solar system was still only a pale nebula, forming a thin crown in the ether a thousand times vaster than the orbit of Neptune, we had all of us been conditioned, determined, irretrievably destined, and your responsibility, my dear child, and mine, and Chevalier's, and all men's, were not only watered down, but abolished, in advance. All our movements, caused by previous movements of matter, are subject to the laws which govern cosmic forces, and the human mechanism is only a particular instance of the universal mechanism.⁹

For mechanical determinism, chance is but "a word without any meaning," since "we employ the word chance solely to conceal our ignorance of the natural cause that produces the effects we see."¹⁰ The best-known representative of this tendency is Laplace (1749-1827), who carries to an extreme the Encyclopaedists' negative attitude towards chance, maintaining that final causes as well as chance "entirely disappear for the sound philosophy that sees in them but an expression of our ignorance as regards the real causes."¹¹ Fortunately, he was inconsistent enough to recommend the study and application of probability theory.¹²

Only a few classical determinists remain in the field of physics today. Einstein is perhaps the last of them. There are two main reasons for the eclipse of determinism, aside from the philosophical criticism made by dialectical materialism. One of these reasons is the revival of indeterminism as an aspect of irrationalism, a theme which will be dealt with later. The second factor is that, far from confirming the determinists' prophecies, the progress of science not only did not lessen the domain of chance but has brought it to the foreground—as is shown by the Brownian movement, radioactivity and microphysics in general. Chance, instead of being gradually eliminated, has become better known, and as a matter of fact no

⁹ A. France, *Histoire comique*, ch. IX.

¹⁰ P. H. d'Holbach, *Le Système de la nature*, ch. V.

¹¹ P.-S. La Place, *Essai philosophique sur les probabilités* (Paris, 1921), I, p. 2.

¹² *Op. cit.*, I, p. 106.

modern physicist believes now that "accidental" is contrary to "regular." So long as mechanical causality reigned in science without challenge, chance was considered as a subjective category and law was defined by causality and identified with it. Now that it is acknowledged that causality is not the sole manifestation of necessity, but the most elementary and schematic form of reciprocal action; now that we know that accidents not only have their laws but are as real as necessary events, law ceases to be synonymous with the causal.

The metaphysics which does not accept determinism falls into accidentalism, according to which everything is contingent in the last analysis, necessity being a result of the statistical compensation of accidental events. The extreme and most conspicuous representative of this tendency nowadays is Johann von Neumann, who does not even accept the validity of causality on the macroscopic scale. He declares that "the apparent causal arrangement on a large scale (that is, the universe of objects perceivable by the naked eye) has surely no other cause [*sic*] than the 'law of large numbers'."¹³ This is not, of course, a conclusion from quantum theory, but rather from the Machist epistemology which Neumann upholds when he states that the "elements" of reality are perceptions; the results of measurements (which are acts of perception) form statistical assemblies, that is to say, sets of elements distributed at random; hence, (*my*) "experience" leads to indeterminism.¹⁴

Both deterministic and indeterministic metaphysics define chance in a negative way: the accidental is that which is not necessary, or that which is not ordered. In neither of the two schools do we find an ontological analysis of chance, which thus becomes, not so much a mask for our ignorance as an occasion to exhibit the ignorance of metaphysicians. Once the discussion has been stated in these mutually exclusive terms, the indeterminists must win in the long run. For, by maintaining that chance exists solely in the mind of man, and not being able to glean from this mind the causes of accidents (which

¹³ J. V. Neumann, *Mathematische Grundlagen der Quantenmechanik* (New York, 1943), p. 172.

¹⁴ "Experience leads only to statements of the following type: an observer has performed a certain (subjective) act of perception. It never leads to statements of this kind: A physical quantity has a certain value." *Op. cit.*, p. 224.

appear in growing numbers in scientific research), determinists leave a rich booty in the hands of accidentalism. Once the reality of chance has been demonstrated in daily scientific work, the classical determinist who reasons in a metaphysical way has nothing left but to abandon the battlefield, retiring to dream of an utopian age that will restore that strict determinism whose very limitations gave rise to absolute indeterminism.

A dramatic illustration of how classical determinism necessarily leads to indeterminism was Democritus himself, the champion of determinism in antiquity. Because he did not believe in the divine origin of the Universe, and could not find its prime cause, he could only explain its origin as owing to chance. It was the irony of history that Epicurus, the successor of Democritus and of all Ionian materialism, should have been the first to introduce pure chance (the non-caused accident, the fortuitous happening *ex-nihilo*) as an ontological category. Epicurus maintained, alongside Democritus' blind necessity, a blind hazard whose ultimate element was the atom's *clinamen*, or spontaneous departure from its vertical fall. Since the *clinamen* is accidental, the collision of two atoms is a matter of chance; and, as all that exists is constituted by combinations of atoms, even goodness is contingent.¹⁵ This external co-existence of chance and necessity emerges as the result of the axiom of absolute necessity, which Democritus expressed in the famous words, "By necessity were fore-ordained all things that were and are and are to be."

In modern times, it is in classical genetics that the metaphysical categories of chance and necessity fight each other inconclusively. On the one hand, the partisans of Mendel and Weissmann maintain that descent is strictly and exclusively predetermined by chromosomes. In this, fatalism is absolute and nothing remains of the chance that appeared in Lamarck's processes of adaptation to envi-

¹⁵ Epicurus needed these spontaneous movements in order to account, by means of the atomic theory, for the free will which was absent from Democritus and indispensable for the struggle against the political and religious power. See Far-
rington, *op. cit.*, p. 148 ff. As for the differences between Democritus and Epicurus,
cf. Marx, *Différence de la philosophie de la nature chez Démocrite et Epicure*,
transl. by J. Molitor, *Oeuvres Philosophiques de K. Marx* (Paris, 1927), I.

ronment or in Darwin's selection as the result of the struggle for existence. But, on the other hand, the same classical geneticists admit that the combination of genes, sole and invariable bearers of inherited characters, occurs by chance, in the style of Epicurus' atoms. That is to say, on the one hand the laws of heredity are immutable and we can do nothing to modify them save in a negative way, by eugenics. If Lysenko claims to have modified this fatal destiny in a constructive way, this is decried as Soviet propaganda. On the other hand, the result of crossing sexual cells is as chance-like as dice-throwing. Hence, in classical genetics the purest brand of Stoic and Augustinian fatalism is juxtaposed to the crudest variety of accidentalism. Here, as in the Greek tragedies, fate operates at random.

What is it that has brought determinism into its present disfavor? Purely logical considerations, like Hume's old criticism? Or perhaps has science, our guide for causal action, found that at bottom all things are contingent? Is it only a coincidence that indeterminism is as much favored nowadays as determinism was a century ago? Is it also coincidental that the ideologists of capitalism's period of decay should proclaim the dictatorship of chance in the same way as the bourgeois scientists of its ascending period proclaimed causality's republic? Was it by chance that the Encyclopaedists and Laplace proclaimed the omnipotence of determinism and Adam Smith and Ricardo sought to discover, behind the apparent and real accidents of capitalist economy, its necessary laws? Is it by chance that nowadays the champion of indeterminism in physics and in economy is one and the same person, J. von Neumann, an eminent mathematician and well-known follower of Mach? Is it accidental that existentialism, that fascist form of bourgeois nihilism, should revive absolute free-will, rejecting causal explanation in history? Was it by chance that the worship of the goddess Tyché should spread at the time of the ancient world's disintegration, once Platonism had proscribed Ionian science and materialism, which looked for the world's explanation and did not passively acquiesce in divine order? Was it by chance that the early Christians should oppose the blind Tyché which symbolized the Greco-Roman society's breakdown? And, finally, is it also by chance that Marxists, instead

of going back to accidentalism after the defeat of mechanical determinism, should go forward dialectically from both?

The false dilemmas of necessity and chance, determinism and indeterminism, are but particular instances of what Hegel called the metaphysical mode of thought. Bourgeois science does not know of a way out. It must have *either* determinism *or* indeterminism. Its attitude as regards this metaphysical disjunctive was described by Engels three quarters of a century ago when he wrote: "Another contradiction in which metaphysics is entangled is that of chance and necessity. What can be more sharply contradictory than these two thought determinations? How is it possible that both are identical, that the accidental is necessary and the necessary is also accidental? Commonsense, and with it the great majority of natural scientists, treats necessity and chance as determinations that exclude one another once for all. A thing, a circumstance, a process is either accidental or necessary, but not both. Hence both exist side by side in nature; nature contains all sorts of objects and processes, of which some are accidental, the others necessary, and it is only a matter of not confusing the two sorts with one another."¹⁶

III. THE DIALECTICAL SYNTHESIS

There is a way out from the disjunctive, chance-necessity, and this solution is to be found in dialectical materialism, which is neither determinist nor indeterminist. "One knows that what is maintained to be necessary is composed of sheer accidents and that the so-called accidental is the form behind which necessity hides itself—and so on."¹⁷ For the dialectical method, chance and necessity are opposites, but dialectical opposites that interpenetrate and convert into each other, not absolute and external determinations. The contingent has its causes and there are, in turn, accidental causes. The accidental can become necessary and viceversa. That which is accidental on a certain quantitative level or at a given historical stage of knowledge may become necessary on another level or at another stage of science, and vice versa.

¹⁶ Engels, *Dialectics of Nature*, (London, 1940), p. 230.

¹⁷ Engels, *Ludwig Feuerbach*, in *Selected Works* (Moscow, 1950), II, p. 351.

For the metaphysical mode of thought possibility, which is the essence of the contingent, either does not exist as an ontological object, or else it is the primary form of existence. In the first case, a thing is or shall be, or else it is not and shall not be. In the second case, an event not fore-ordained is absolutely undetermined. In both cases the end point is the same—religion, whether by way of teleology (mechanical or divine) or by way of absolute free will. On the other hand, for the dialectical method there are infinite gradations between being and not-being, the determined and the contingent, as well as between certain knowledge and total ignorance. For dialectical materialism the “lines” of development are not linear, but rather networks of reciprocal actions. At a given stage, the development *may* proceed in this or that direction; in that case, however, this or that possibility, that was not fore-ordained, ceases to be necessary.

Materialism shares the thesis of Leukippos, one of its founders: “Nothing happens without a reason but everything through a cause and of necessity.” Everything that exists is necessary, nothing happens *ex nihilo*. But dialectical materialism, in contrast with mechanical materialism, instead of dogmatically denying chance, adds that the contingent is as real as the necessary, that chance is something more than a word to disguise our ignorance, being in return an object, ontological as well as epistemological, worthy of examination. In this point, modern materialism comes close to Aristotle, for whom fortuitous events were as real as necessary ones.¹⁸ But for Marxism the contingent is not (outside of the human realm) the crossing or the frustration of finalities, as it was to Aristotle. “In nature—in so far as we ignore man’s reaction upon nature—there are only blind, unconscious agencies acting upon one another, out of whose interplay the general law comes into operation. Nothing of all that happens—whether in the innumerable apparent accidents observable upon the surface, or in the ultimate results which confirm the regularity inherent in these accidents—happens as a consciously desired aim.”¹⁹

¹⁸ See Aristotle, *Physics*, Bk. II, 4-6.

¹⁹ Engels, *Ludwig Feuerbach*, p. 353 f.

How is it possible to maintain the compatibility of the necessary interconnection of all things with the objective existence of chance? Cournot emphasized that there is contingency only when the crossing causal lines are entirely *independent* of each other. On the other hand, ever since Heraclitus dialectics has maintained that, weak as the ties may be, they always exist. However, this is not enough: Contingent events consisting in intersections of "causal lines" are characterized just by being "things and events, whose inner connexion is so remote or so impossible of proof that we can regard it as non-existent, as negligible."²⁰ Does this mean, then, that (relative) *independence* of two or more events conjoined by chance is the essence of the contingent? Yes and no. In this type of contingent events, there *was* independence (practically) up to the instant of crossing. This kind of accident is the point at which two independent processes *cease* to be independent; as soon as the crossing has taken place, the accident has become a necessary fact modifying its constituent elements and giving origin to new lines of development. This is the case, of course, with real accidents, not with subjective *coincidences*. Let us make it clear by a couple of examples.

A comet strikes the Earth annihilating the human species. According to the laws of celestial mechanics, this event is predetermined, but as Cournot pointed out, it is nonetheless accidental (in the epistemological sense, as it was not foreseen). And, as Engels remarked (on a different case), "the assertion that the case was foreseen already in the primordial constitution of the solar system does not get us a step further."²¹ If we verbally deny that this is an accident, we are not able to predict it in a certain way, to prevent its probable prediction. Thus far we are according with the determinism which, while acknowledging the objective reality of chance, wishes to "reconcile" it externally with necessity. What the metaphysician is unable to see is that the accidental may become necessary. In the above-mentioned example, the crossing of both processes being a new process that modifies the former ones. It becomes the point of departure of a necessary process. The accidental has become

²⁰ Engels, letter to J. Bloch (September 21, 1890), *Correspondence of K. Marx and F. Engels* (London, 1936), p. 475.

²¹ Engels, *Dialectics of Nature*, p. 232.

necessary; that which had been independent has ceased to be so; and thus chance becomes a manifestation of the universality of inter-connection.

This objective kind of accidents should not be confused with simple *coincidence*. It was a coincidence (a subjective accident) that on the same instant as the last world war broke out, John Smith should die of cancer in Australia. The independence of both events was practically absolute before and after. Cournot's definition applies only to this kind of apparent or subjective accidents. Hence (real) contingency is not excluded from the universal inter-connection, but is a part of it.

The strictly causal definition of contingency, in the manner of Chrysippus or Cournot, who "reconcile" both opposites instead of uniting them, relies upon two basic errors typical of mechanism: a) that the causal relation is the sole form of necessity, so that every accident remains *eo ipso* excluded from the relation of necessity and we are only left with the possibility of obtaining external statistical regularities happening in a mysterious way; b) that knowledge is a product of nature, and at the same time not a producer of things. Hence (this conclusion was not Cournot's) that passive clay we call the external world, will be gradually freed from contingency as its secrets become known to us. But man does not only know and produce casual chains, but also contingent events. For every chance he defeats he creates other accidents. Thereby the progress of learning and of mastering nature and life does not bring with it the quantitative reduction but the qualitative modification of the domain of chance. "Growth of knowledge [it has been rightly said] makes possible new ways of acting and thus paves the way for unpredictable interactions"; "no amount of knowledge (at least knowledge as we know it) will ever permit us to read the future like an open book, precisely because knowledge, as long as it advances, is one of the very factors changing that future."²²

That degree of absolute knowledge, that total elimination of contingency in things and of uncertainty in the mind is, therefore, a determinist phantasy. That is a typical utopia of mechanism,

²² J. Katz, "On chance and prediction," *Journal of Philosophy*, vol. 41, (1944), p. 630 f.

which is incapable of explaining novelty—new things that often arise, precisely, as accidental leaps. We have already stated that absolute determinism leads inevitably to indeterminism. But further, if determinism is consistently maintained, not only agnosticism but also charlatanry may emerge: astrology, spiritualism, and chiromancy are typically deterministic. The astrologer, be he Chaldean, Stoic or New Yorker, wants to predict and explain the future by means of a deterministic and mystical “explanation” of certain subjective coincidences. He (or at least his clients) believes that every human fate is fore-ordained and can be read in celestial bodies.

Once we have established that we must analyze chance and not be satisfied with dogmatically accepting or rejecting it, the problem of the method of analysis arises. The accidental is a real object, not only a logical category, so that an analysis of chance should contain an examination of contingency *in re* (ontological analysis) and not solely its methodological elucidation. However, for Marxism there is no autonomous philosophy, independent of science, but philosophy is essentially theory of science—the epistemology and logic of scientific research.²³ How then can we carry on that philosophical analysis of facts to the realm of science which is genuine ontology? If this examination is direct, if it is not based on the data of scientific knowledge, the danger exists of repeating the mistakes of the Romantic Philosophy of Nature or of idealist ontology. Hence, when performing an ontological examination of contingency, it is necessary to base it on the knowledge of fortuitous events that the several particular sciences give us. A methodological analysis could not lead to conclusions alien to those of the ontological examination, since ontology and epistemology are inseparable for Marxism. However, the distinction between the two analyses is useful, since the problem is not only to inquire into the *form* given to contingency for its adaptation to scientific analysis, but also to inquire into the *nature* of chance events.

23 For the first statement, see Marx, *Idéologie Allemande, Oeuvres Philosophiques*, transl. by Molitor (Paris, 1937), VI, p. 159. For philosophy's reduction to epistemology and logic, see Engels, *Anti-Dühring, Marx-Engels Gesamtausgabe* (Moscow, 1935), p. 28. This controversial point has been dealt with by the author in “¿Qué es la Epistemología?,” *Minerva*, I, 27 ff. (1944).

IV. ANALYSIS OF CONTINGENCY

Before we analyze contingency it will be convenient to define it, even though we know that any non-arbitrary definition is a result of analysis, and not its point of departure. Let us try the following complementary definitions of contingency:

Ontological definition: An event is accidental, fortuitous, or contingent *when it may be or not be*.

Epistemological or methodological definition: Contingent is all that which *cannot be predicted with certainty*, whether because it has no causal law of its own, or because we are ignorant of its law, or because we do not know with enough precision the circumstances (e.g. the initial conditions) which permit its certain prediction.

These definitions are complementary and inseparable as ontology and epistemology are. If we know that something *may* or *may not* be, it is in virtue of previous data about similar events; and if we cannot foresee it with certainty, it is precisely because, at least in our present state of knowledge, it is *possible* and not inevitable. As a consequence of this intimate binding of ontology and epistemology, we cannot neatly separate physical from logical contingency. This distinction will always be provisional. The contingent is both that which is not subject to the fatalist *must be* of mechanical determinism, and that which cannot be predicted with certainty. Let us begin with an ontological examination of contingency.

ONTOLOGICAL EXAMINATION

Contingency embraces, in our opinion, several sorts of facts—facts different from one another in nature. Without pretending to give a complete classification, we may distinguish among three major types of accidents: 1) small variations in the causes produce great differences in the effects; 2) unforeseen leaps in development (modification of the law of self-movement); 3) crossings of lines of development. This classification should be understood like every other classification, as a relatively arbitrary and elastic division. Since the subject is difficult and elusive, it will be convenient to proceed

cautiously and, abandoning philosophy's classical form of exposition, go through some concrete examples. (Almost all these examples may be found in the classical treatises on probability calculus.)

1) *Variations in the causes.* This type of chance events was studied by Poincaré. *Example 1.1: Unstable equilibrium.* Let us consider a pyramid resting on its vertex. We know that it is going to fall, but we cannot predict with certainty when, nor on which of its sides. The causes contributing to its fall are multiple, such as slight deviations from geometrical symmetry, small heterogeneities in material, a little tremor, or a puff of wind. The event is a complex one. The *possible* causes are not quantitatively measurable, and we do not have even the possibility of ascertaining which accidental causes came into operation.

Example 1.2: Errors in measurement. Even supposing the observer may eliminate or at least isolate the constant causes of error (systematic errors), there always remain accidental errors, associated with causes as numerous as they are complex, and which may be attributed as much to the variation of the circumstances accompanying the measurement acts, as to the fluctuations taking place in the measuring device, the object under observation and the interrelation of the two.

Example 1.3: The game of roulette. A small difference in the initial momentum imparted to the ball produces a great difference in its final position on account of its great number of revolutions, of the variation of friction with velocity, etc.

2) *Leaps.* Leaps are alterations of the law of the self-movement of a given process; they may be spontaneous or originated by external agents. Accidental leaps of course did not fit into mechanical determinism.

Example 2.1: Radioactive disintegration. The event's remote cause is the decaying nucleus' instability. But we do not know the immediate cause whereby the nucleus decays precisely at the instant it does. Employing the Aristotelian terminology, we may say that we know the material cause but not the efficient one.

Example 2.2: Spontaneous light emission. An atom on an excited level will emit light without external perturbations being needed (much the same as in the foregoing example). In this case

too we know the material cause (the previous excitation undergone by the atom, which is the necessary condition for its accidental leap), but we do not know precisely why it should emit now and not a fraction of a microsecond later.²⁴

Example 2.3: Molecule formation. In certain conditions two hydrogen atoms combine in a molecule. (Here we have also an intersection of lines of movement, and that which was independent has ceased to be so with the conversion of the accidental into the necessary.) But there are *two* (equal) possibilities: that the molecule be of parahydrogen or orthohydrogen, without the individual atoms "knowing" beforehand which form will prevail, and without there being any objective "force" impelling them to one or the other "destiny." Once more, we know the material cause: the first kind of molecule will come into being if the spins of both nuclei add, and parahydrogen will be formed if they subtract. The result, however necessary and well-determined by the spin interaction, is not predictable as regards *one* particular event.

3) *Crossings of development lines.* We have seen already that this is the only kind of objective chance that determinism thinks compatible with necessity.²⁵

Example 3.1: Frustrated germination. By an unforeseen (accidental) cause, the seed that we threw on fertile ground is carried onto a stone by a puff of wind. The causal chain we wanted to originate has been interrupted by another development line, external to the former until the intersection point.

Example 3.2: The birth of a great man. On the one hand, we have the (contingent though necessary) crossing of two biological

²⁴ Two remarks are necessary with regard to examples 2.1 and 2.2: a) Both seem to be purely *quantitative* leaps if isolated and if no qualitative modification occurs within the atom. They become qualitative leaps as soon as we remember that in each case a novelty has arisen, viz, the particles or photons emitted. b) In the present stage of science both events are contingent ontologically as well is epistemologically. Nevertheless, attempts are being made to explain the latter phenomenon causally, i.e., to find the efficient cause of spontaneous omission. Cf. the author's article on "The Inexhaustible Electron," *SCIENCE & SOCIETY*, XIV, 118 (1950).

²⁵ Let us recall that, for mechanism, development lines are: a) causal, linear, single-directed; b) external to each other (when conjoined by chance) before and after their crossing.

lines; on the other hand, the exceptional individual's adaptation to the needs of his time, the crossing of an individual "destiny" with a collective "destiny"—and this accidental crossing also was necessary.

Example 3.3: Traffic accident. Until the instant of its happening there was no causal relation between the victim and the car.

METHODOLOGICAL EXAMINATION

In order to calculate chance, in order to be able to find its laws and thereby predict (in a probable way) individual contingencies and (with certainty) the mass results of great numbers of accidental events (all of the same kind) it is necessary to go over, from the ontological classification, to a *formal* classification that does not pay attention to the nature of contingent events—a nature whose determination pertains to the science to which they correspond.

Marcel Boll, the brilliant and inconsistent French positivist, has made a dialectical analysis of the relations of dependence between two events or groups of events.²⁶ Let x and y be two elements or groups of mutually related elements (things, facts, processes). The narrowness of this relation will depend, of course, on its nature. But what we are interested in is its mathematical form, not its mathematical nature. From this point of view three degrees or types of dependence may be distinguished: A) *chance* (total indetermination—when one of the elements is known and the other cannot be determined); B) *contingency* (partial determination—where a necessary but not a unique relation exists among x , y and the probability p); C) *necessity* (total determination—the value of x unequivocally determines that of y).

A) *Chance*. Indeterminacy is absolute, nevertheless uncertainty is partial as soon as we know (on the basis of previous experience)

²⁶ M. Boll, *Attardés et Précurseurs-Les Tendances Actuelles de la Philosophie Française* (Paris, 1921), p. 195. It should be borne in mind that we are dealing here with the *form*, not with the content of dependence relationships. According to positivism *only* the form of dependence relations (among perceptual elements) and the psychological content of related elements should be investigated. Accordingly, Mach tried to replace causality as an objective material relation by the mathematical concept of function, and Pearson by the statistical concept of correlation.

the event's probability p . Since the answer's value (y) remains undetermined, the law of chance is $f(x, p) = 0$.

Example A.1: Coin-tossing—If the coin is tossed only *once* there will be chance: knowing the number x ($=1$) of tossings is not enough to determine unequivocally the frequency y with which a head is going to turn out. (The variable y may be 0 or 1 with equal probability— $p = 1/2$, a fixed number.)

Example A.2: Urn. When an urn contains x numbered balls which one will come out in one drawing? There are x equally probable answers.

Example A.3: Radioactive decay. It cannot be predicted with certainty at which instant a given nucleus is going to disintegrate. However, analysis of a great number of events of this kind permits us to evaluate the probabilities of decay per second.

B) *Contingency*. In this intermediate case between chance and necessity, determinacy is incomplete. There is a necessary connection among the datum x , the answer y and the probability p of the latter. The law of contingency is $f(x, y, p) = 0$.

Example B.1: Coin-tossing. How many heads will turn up in 4 tosses? There are five answers, not one, that is—0, 1, 2, 3, 4 heads. In general, for x tosses there will be $(x + 1)$ possible answers, but these are not equally undetermined or equiprobable, because it is an empirical fact that the most probable frequency is $x:2$, corresponding to $p = 1/2$.

Example B.2: Pyramid in unstable equilibrium (cf. Ex. 1.1). We cannot foresee on which one of its x sides the pyramid is going to fall, but if there are no asymmetries we may suppose that the x possibilities are equiprobable.

Example B.3: Germination. Let us suppose we have a plant in seed; we divide its environment into two equal sectors, the one fertile and the other sterile, and we suppose that the seeds are scattered at random. In the case of one seed there is chance. Two equally undetermined answers are possible. For 4 seeds there are 5 answers to the question of germination; but these 5 answers are not wholly undetermined. The seeds' distribution is not absolutely at random one (cf. Ex. B.1).

C) *Necessity*. When the problem is thoroughly determined, it has only one solution provided the law (the function f) and the

values of x and y are exactly known. The law of necessity is $f(x, y) = 0$.

Example C.1: Geometry. Given the diameter x of a circle, its length y is unequivocally determined by x .

Example C.2: The (mechanical) state of a moving (macroscopic) body at a given time is exactly determined by its previous states—that is, we can predict its evolution if we know the initial conditions.

Example C.3: Coin-tossing. As the number x of tosses increases, the frequencies of the events “head” and “tail” stabilize themselves, tending (irregularity, without law) to equal each other. The law of large numbers teaches us that, for a great number of tosses, the result ceases to be contingent and becomes necessary (as many heads as tails).

DIALECTICS OF CHANCE

The three above mentioned formal gradations (pure possibility, conditional possibility and necessary determinacy) are not absolute but relative. In the case of coin-tossing for example, transitions from one to the other are changes of quantity into quality—that which is pure chance for one event becomes contingency or conditioned chance for more than one and statistical necessity for a large number of accidental elements. Radioactive decay is another typical instance of the formation of necessity by means of a large number of contingencies. A great number of radioactive nuclei obey a (statistical) law that is as necessary as the falling of a stone. From this collective law (proper to the population, not to every one of its elements) we can infer the “mean behavior” of each nucleus (for example, its mean life) in the same way as we calculate the mean life of a community, without being able to predict with certainty the lifetime of each human being.

What is necessary may consist in a large number of accidents. But not only that; conversely, contingency may be composed of a group of necessary events. Necessity is as much contained in chance as chance is in necessity. In reality we have not the juxtaposition but the interpenetration of chance and necessity. An example of this was given above in the crossings of development lines. Another instance is afforded by a more detailed analysis of Ex. C.2. A small

variation (or a little error in measurement) in initial values leads to a great difference in the final state (cf. Class 1 of contingent events). The final state is then contingent. Knowledge of it is uncertain—even though the law of the process is known. This instance shows, once more, that it is not always our ignorance of the dynamic law which compels us to say that an event is fortuitous.

Let us examine further instances of the dialectical transformation of chance into necessity and vice versa. It is often asserted that mathematics is alien to chance, and this is true in the following senses: 1) mathematical reasoning draws *necessary* conclusions from sets of hypotheses or axioms, even in the case of probability theory; 2) mathematics does not *directly* deal with contingent events, but examines them from the formal point of view, once they have gone through the sieve of statistics.

The assertion that mathematics is alien to chance is however not true when the fact is considered that behind every necessity a contingent element may be discovered. The methods used for the analysis of chance are also applicable, in many cases, to the analysis of necessity; that is to say, the causal and the statistical approach can sometimes be applied to one and the same problem. One instance of the utility of this approach is that the probability of convergence of a given series may be studied before ascertaining its actual convergence or divergence, even though a series is the most typical example of a constructed logical necessity.

As a second example, let us take the so-called normal numbers. If we take at random any number within the interval from 0 to 1 and consider a sufficiently large number of decimals of that number, we shall practically with certainty obtain the result that the ten digits from 0 to 9 appear with the same frequency, $1/10$. This equipartition amounts to saying that the probability of "drawing" at random any one of these digits is the same for normal numbers, which constitute "almost all" the numbers lying between 0 and 1. That is, the law governing the position of every digit is one of strict determination, but as soon as we go over from one decimal to the complete set, a random distribution appears, a statistical quality arises which is proper to large assemblies of like elements.

Another typical instance of the interplay of chance and necessity

is afforded by statistical mechanics, whose central reasoning is clearly exhibited in dice throwing.²⁷

When we throw a regular die whose faces are not numbered, obviously it will always fall on some one of its faces; from a "macroscopic" point of view its final state is always the same. If we distinguish among its faces by numbering them—that is, if we introduce the "microscopic" point of view, one and the same state is now compatible with six microscopic states. As we cannot predict with certainty which one of the six states will be realized, we have an uncertainty. We have negated the initial certainty of the macroscopical description. But if we repeat the throwing many times, we obtain exact results, to any desired degree of accuracy; e.g., the mean value of the spots is $(1+2+3+4+5+6) \div 6 = 3.5$, the six faces appear, each with the same frequency. We have thus obtained *statistical* laws, as accurate and strict as the dynamic ones. We have negated the negation, obtaining a higher level. Yet, we can perform a new negation. From the statistical point of view we may go back to the consideration of an isolated fact, of the "microscopic" individual state. Hence we ask for the *probability* of obtaining two "*sixes*" in succession, etc. The answer to this question will be given by previous experience with the conversion of empirical frequencies into probabilities. In one and the same instance we have verified the operation of the three elementary laws of dialectics: transformation of quantity into quality and vice versa, negation of the negation and the very kernel of dialectics, namely the unity of opposites.

CONCLUSION

We may sum up the results thus far obtained as follows:

- a) For dialectical materialism contingency is as objective a category as necessity;
- b) Contingency does not constitute an exception to the universality of interconnection and reciprocal action, but is a form of their existence;
- c) Necessity and chance are not mutually exclusive nor external

²⁷ The analogy comes from M. Planck, *Introduction to Theoretical Physics* (London, 1932), v, p. 224.

to each other: "chance is only one pole of an interrelation, the other pole of which is called necessity."²⁸

d) In reality, as well as in the knowledge of reality, chance and necessity convert one into the other according to the general laws of dialectics.

e) The progress of knowledge does not involve a gradual elimination of chance, since the latter exists not only in knowledge but also in things, and in natural objects as well as in those produced by man. The progress of knowledge, in this respect, consists in the mastering of chance by way of recognizing it, not in dogmatically rejecting it.²⁹

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²⁸ Engels, *The Origin of Family, etc., Selected Works*, II, p. 293.

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