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Charles Peirce and Quantum Mechanics

Of the two basic ideas of quantum mechanics, probabilistic causality and discontinuity, it is the second that constituted the sharpest break (discontinuity) with the past. Yet, with the wisdom of hindsight, we can see that, in an indirect way, this idea, too, was not wholly new.

That the basic regularities of nature might be irreducibly statistical was suggested by two great men of the last century, Clerk Maxwell and Charles Peirce, that is, a great physicist and a great logician-experimental-scientist-philosopher.¹ Both saw that the laws of gases, which were generally taken to be probabilistic only because of our ignorance of details, might instead, for all we could know, conceal a multitude of bits of randomness. Both also had other reasons, especially so in the case of Peirce. The French philosopher Emile Boutroux had similar notions.²

As for discontinuity, in one sense this was almost a truism in prequantum thought. In geometry, half an area or volume is a smaller area or volume in the same basic sense as the entire area. Space, geometrically regarded, is continuous, or at least infinitely divisible. But reality in space was not usually thought of as continuous. Half an animal is not a smaller animal, half a cell not a smaller cell, and half an atom not a smaller atom. The whole idea of the world as a plurality of substances usually meant that reality was quantized in space. When light was thought of as "corpuscular" this was an illustration of the same way of thinking. It was only time and, with time, motion and energy that were exempted from the quantum principle.

Continuity is a maximum of possibility: in the continuum of space there is room for every conceivable size and shape; in the continuum of space-time there is room for every conceivable motion and change. Discreteness means the exclusion of portions of this infinity of possibilities. Very well, what is actuality but such an exclusion? Either the actual world is every possible world in one, or it is not. If not, and few beside Spinoza have believed in the exhaustive actualization of possibilities, then in principle

there must be quantization, at least if the exclusion of possibilities is subject to any general rule or regularity. And why should this exclusion affect space but not time? In this, present quantum physics and relativity physics do indeed belong together. It is space-time, not just space, that characterizes reality. And Einstein's resistance to the probabilistic aspect of quantum physics, of which he was a chief creator, was an unwitting departure from his own greatest insight.

An interesting illustration of the question of quantization is found in the history of Greek atomism. Democritus held that atoms occurred in all possible sizes; Epicurus demurred, pointing out that there would then be atoms on the macroscopic as well as invisibly small scale. One would like to think that this was not his ultimate reason. The ultimate reason is just the recognition that actualization of possibility in principle rules out something otherwise and antecedently possible. To put blue in just this part of a painting excludes putting yellow there, and vice versa. Actualization is in principle exclusive. To have a coherent world with atoms or cells of certain sizes and shapes rules out worlds with atoms or cells of many geometrically possible sizes or shapes. I assume here that the world must be finite spatially, to have definite character as a whole. Worlds of an infinity of diverse sizes are possible, but any actual world must have its size, at least at a given moment. Since atoms occupy more than points of space, the number of individual atoms must also be finite. And if there are to be many examples of a single kind, the number of kinds must be further limited. Thus if there are to be definite classes of atoms (and if not, the possibility of empirical knowledge of that world is ruled out) any world must have limitations upon the sizes of its simplest constituents which are more severe than the limitations upon the numbers of those constituents.

Similar principles apply to temporal sizes of events. To have a coherent and knowable world with events of certain kinds and certain time lengths rules out worlds with events of many other possible lengths. Just as half an animal, cell, or atom is not an animal, cell, or atom, so half a single event (e.g., an experience) is not an event, a real unit-becoming, but a merely conceptual entity. Only the Buddhists, a few Mohammedans, and William James, with his concept of unit experiences, successive specious presents, drops of experience, seem to have reached this point of view prior to quantum physics. Whitehead accepted and generalized the principle. He perhaps did not know the Buddhist version.

It is remarkable that Peirce not only did not anticipate quantization in

physics, he affirmed actual continuity with emphasis and enthusiasm. And he justified this "synechism" by the argument: continuity keeps all the possibilities open, hence we should take continuous action as our hypothesis, and see how far we can go empirically with it. Otherwise we are ruling out some possibilities a priori.³ I submit that this argument involves a subtle confusion. Discontinuity as a principle rules out nothing except the one infinitely extreme supposedly possible case, continuity. It leaves entirely open the question, Which among the infinitely varied possible discontinuities are the actual ones? And if one asks what is the totality of possible discontinuities, the answer seems to be it is the continuity itself. Merely to say, "not everything possible is actual" is not to close one's eyes to any genuine possibility. For the exhaustive or continuous actualization of possibility is the one clearly impossible hypothesis! To rule it out does no harm, indeed it frees us to look for the only genuine possibilities, that is, the various conceivable *forms of discontinuity*, or partial exclusion of possibility. Many things, as Leibniz so brilliantly said once for all, are possible that are not compossible. It is pathetic that Peirce, so penetrating at many points, fell down at this point. It was Peirce himself who pointed out that the possible, the general, and the continuous are ultimately the same.⁴ And it was Peirce who in his day most clearly affirmed the universal contingency of actualization.

How then could Peirce have fallen into his "synechistic" error? A possible explanation is the following. He was concerned to avoid nominalism, meaning by this the reduction of reality to a single uniform modality, whether this be actuality, possibility, necessity; whether it be particularity or generality.⁵ And he thought that the way to carry through this realistic program was to affirm the continuousness of becoming. The past then could be particular, the future irreducibly general or potential, the present somehow both. Here again I think that the reasoning has gone astray, even more subtly in this case. Possibility is futurity as such. Peirce's indeterminism or tychism was no arbitrary feature of his thought but central and essential to it. But to say that possibility as well as actuality is real, and real as futurity, is not to say that possibility is exhaustively actualized. Futurity is real because it is an essential aspect of presentness. To be present is to face a future. A present without a future is nonsense. But it does not follow that the becoming of the future exhibits all conceivable temporal divisions, which is what continuous becoming must do.

It should be clear from the foregoing that I do not regard the most abstract general principles of quantum mechanics as empirical. Neither prob-

abilistic causality nor spatiotemporal discreteness seem to me to have genuinely conceivable alternatives. It is the particular forms the probabilities and discontinuities take that experience alone can tell us. But we never should have expected nature to exhibit either sheer regularity or sheer continuity. These are a priori mistakes. The alleged fact that Heisenberg's Uncertainty Principle can perhaps (a moot point) be explained away, à la de Broglie, by postulating hidden variables at most simply brings out, in my opinion, the nonempirical status of discreteness and probability as such. The basic reason for accepting them is that otherwise we have no coherent logic for our ideas of possibility and actuality.

Peirce argued that, given continuous variables, exact measurement is impossible; hence determinism taken absolutely cannot have empirical meaning. But he failed to see that if the world has both continuous and discontinuous aspects then, a fortiori, exact causal laws cannot apply. For the interplay of continuous and discontinuous aspects forbids such laws. Thus if photons of light are being partly reflected and partly refracted by a medium such as glass, with a given photon the issue, reflection or refraction, is decided probabilistically by the angle of incidence. This angle is conceived to vary continuously. But the discontinuity between reflection and refraction is made congruous with the continuous variation in the angle only by probabilistic laws. (It was a mathematician whose article made me aware of this point.) Probability, as Peirce remarked, is a continuous variable. According to a standard interpretation (Born's, I believe) as I (very partially) understand it, the continuous aspects in quantum physics are those of real possibility, the discrete aspects those of actual happenings. This fits Peirce's view when he was not blinded by his attachment to continuity, an attitude which he inherited from Benjamin Peirce, his father. It also fits Whitehead's (and von Wright's) doctrine of becoming.⁶

There are two ways to conceive the contingency of the actual, in its contrast to the possible. One is the deterministic way, which amounts to the supposition that contingency comes in a single wholesale dose back of the beginning, if there was a beginning, or back of the infinity of past actuality, if there was not a beginning. I call this, for obvious reasons, the supernatural idea of contingency. The other, the naturalistic version, says that contingency comes into the world piecemeal, in minute doses, here, there, and everywhere, now, then, and always, as "the indeterminate future becomes the irrevocable past" (Peirce). In this view contingency is naturalized, whereas in the deterministic version it is made into a super-

natural mystery. Other actual worlds were possible, but nowhere in the actual world (according to determinism) do we encounter the transition from the indeterminately possible to the determinately actual.

Peirce was perfectly clear about this issue and, I submit, his tychism is its reasonable solution. But then his synechism, as a doctrine of actuality, is mistaken. The transition from natural or real indeterminate possibilities to definite actualities should mean that out of a continuity of future possibilities comes a discrete series of past actualizations. The nearest Peirce came to this is in his term "infinitesimal" (whatever that means) for present experience, and in his once remarking that perhaps experiences do come in least units (doubtless with William James's doctrine in mind) but that we have no knowledge of such units.⁷ Whitehead grants that we lack distinct introspective clarity about the units, but then both Peirce and Whitehead are emphatic about the lack of distinctness of human introspections. Moreover, we do seem to have relatively definite indications as to the length of a single unit experience as measured in physical time. Whitehead suggests 1/10 of a second. It is certainly less than a second and more than 1/100 of a second, since the number of successive musical notes that can be given as successive is far more than one and far less than 100.

To be fair we must remark that Peirce gives an argument for the infinitesimal length of the present. If it were finite then, since in each present there is memory of the immediate past, there would be memory of the mediate past all the way back, which is contrary to fact.⁸ An infinite number of infinitesimal presents can occur in any finite time, and so, Peirce seems to have thought, the vividness of memories of the remote past could become infinitely diminished even in a short time. But if there is any loss of vividness even in a single step in such an infinite series, and if not the infinity will not help, it seems there could be sufficient loss in the large finite number of experiences which on the quantum view must take place even in an hour (ten or more per second, 600 per minute, 36,000 per hour, over half a million per day) to explain the actual fading of our memories. And curiously enough Peirce himself in one writing suggests that forgetting is a matter of degree and is never absolute.⁹ If so he has not shown reason for his infinitesimal present.

The genuinely empirical discovery made by Planck and the others was not that actuality is discrete. So much is knowable a priori and should never have been taken as an empirical issue. The discovery, as with other great scientific discoveries in their empirical aspects, was quantitative, the

arithmetical-geometrical *structure* of the discreteness and of the statistical rules, i.e., Planck's Constant, or Heisenberg's Principle. Merely qualitative issues are philosophical; it is numerical or geometrical definiteness that science alone can provide. This is not to deny that, as human nature goes, philosophers are likely to be misled by bad science and to be helped by good science. Also scientists may be helped by a modicum of good philosophy.

I find something pathetic in Peirce's failure to anticipate both basic aspects of quantum physics, instead of only one of them. For he had all the conceptual tools needed for the second anticipation. Moreover, indicating the right direction for the development of physics was one of his professed ambitions and, he thought, a test of the soundness of his philosophy. Perhaps what he lacked was the availability of colleagues capable of meeting him part way in discussing the issues with which he, almost alone among his contemporaries, was adequately equipped to deal. It should also perhaps be said that since the philosopher's mathematician father, Benjamin Peirce, had espoused a metaphysics in which the idea of continuity was central and, since Charles was deeply indebted intellectually throughout his childhood and youth to his father, there was an emotional factor in his synecism that may have helped to limit his speculative possibilities. Thus he says that if he were to dilate upon the treasures summed up in the idea of continuity, in the words of Mathilda, "the tomb would close over him" before he was done.

Alas, there are also treasures in the idea of discreteness. For it is the idea of actuality, in one of its categorial aspects, just as contingency (and no one ever saw this more clearly than Peirce) is another aspect of the very same idea. Granted that the continuum of conceptual possibilities must be broken up in the process of actualization, it is a logical truth that the *how* of the breaking cannot be specified by the continuum itself. Hence actuality is necessarily contingent. This is a more fundamental truth than any difficulty of exact measurement.¹⁰ There is no better way of missing the point of Heisenberg's partly scientific and partly philosophical discovery, it seems to me, than the supposition that it concerns only limitations in our instruments of observation. It concerns rather the very meanings of "actual" and "possible." Peirce was beautifully clear as to the contingency of actuality as such and the continuity of possibility as such, but somehow he was unclear as to the implied discontinuity of contingent actuality.

According to some interpretations, quantum mechanics (which is not very mechanical) has upset not only the traditional notion of causality but also the traditional idea of substance and in addition the realistic view of nature as independent of the human type of knowing. As to substance, Peirce is ambiguous. He is in a half-way house between substantialism, which Manley Thompson thinks he or we ought to go back to, and an explicit philosophy of unit events. Peirce does talk as though the "logic of events" were the real structure of nature, but he says some things which imply that actuality consists essentially of continuously changing identical individuals. He is forced, as any clear thinking writer must be, to admit that such individuals have no wholly determinate character, and thus the law of excluded middle with respect to predicates lacks absolute application.¹¹ It does not occur to Peirce that unit events might be the really determinate individuals. It could not occur to him, since continuous change cannot consist of definite units.

As to the question of realism, here, too, I fear that Peirce was not free from ambiguity. He defines reality as what scientific inquiry, if sufficiently persisted in, will or would establish agreement upon. This seems a rather subjectivistic explication. Yet the category of Secondness implies independent existents to which our experiences are responding. Present day physics exhibits a somewhat similar ambiguity or hesitation. Schroedinger and Popper have not accepted the subjectivistic version of what physics is doing.¹² My sympathies are with them. I cannot believe that we can know nature only as interacting with us, but I cannot see the impossibility of abstracting from this aspect. A present act of observation has as its data slightly past events, and the past cannot be influenced. There is, however, a form of subjectivism (Whitehead calls it reformed subjectivism) that is perfectly compatible with realism. This form, sometimes called panpsychism, and which I like to call psychicalism (analogous to physicalism) was unambiguously espoused by Peirce. (What seems a still different form, Hindu mystical monism, appears to be Schroedinger's view.)¹³

I wish to support the Peirce-Whitehead form of psychicalism by appealing to an analogy from the history of quantum physics. After Planck had made the world aware that nature was less continuous than had (wrongly, as I argue) been supposed, and after it had been shown that light, usually taken as continuous, had also a discontinuous aspect, de Broglie guessed that electrons, taken as discrete, had also a continuous aspect and involved waves as well as particles. This was a magnificent

intuitive leap. It was as if one were to say, continuity and discontinuity have been shown not to exclude one another, and besides both are too fundamental for either of them to be confined to some one part of nature; rather, the relation between them is the very principle of actuality. Similarly, in our experience the psychical and the physical (meaning essentially what is spatial) are found not to exclude one another, and besides, both are too fundamental for either of them to be confined to some one part of nature; rather the relation between them is the very principle of actuality. On both sides of this analogy, continuous-discontinuous compared to physical-psychical, there is a third concept which mediates between the two contrasting poles. This is the concept of groups or aggregates regarded statistically. Peirce had already realized, no doubt assisted by Leibniz's form of idealism, that the seemingly absolute inertness, deadness, and monotonous behavior of "matter" (in contrast to mind) is an artifact of our sense perceptions which fail to distinguish the active singulars composing the microstructure, which we now know to be the basic dynamic structure, of the physical world. He saw that the seemingly absolute regularities of the macrostructure could be reasonably taken as statistical effects of very high numbers of minute sentient creatures of a limited number of very primitive kinds, with only minimal degrees of "spontaneity" or individual creativity.

According to the standard interpretation of quantum physics, the interplay of continuous and discrete aspects of nature can only be expressed statistically. As Heisenberg said to me once, it is silly to wish to evade the Uncertainty Principle for then the paradox, particles but yet waves, will become a contradiction. My suggestion is: just as continuity and discontinuity, so extendedness and the psychical, are too fundamental and too obviously interrelated to be assigned, the one to this, the other to that portion of nature, and just as the relations of the first pair are rationally expressible only in terms of statistical assemblages and a real contrast between actual and possible, so with the relations of the second pair. The particle and random aspect is the aspect of singular actualities, the wave and law-like aspect, that of plural possibilities or probabilities; similarly the actual singulars in nature are all at least sentient, and in so far forms of mind, but the behavior of statistical assemblages of huge numbers of such singulars, not distinguished from one another in our perceptions, can explain all the observed properties of physical processes.

It is too much to expect that those addicted to the mental cramp of looking only to language, and especially rather concrete and everyday forms

of language, for enlightenment will see much force in the foregoing considerations. But I agree with Popper that too much fascination with words is a trap into which neither scientists nor philosophers ought to fall. Instances of spatial extendedness and experiencing are given as extralinguistic realities, and the question of dualism has to be faced. It has never been shown that materialism is the only or even a genuine alternative to dualism. Moreover, if it is particulate singulars which are actual and to which no known deterministic laws apply, while the continuous and deterministic aspect concerns the probable occurrences of very large numbers of singulars, then it is time to take seriously the central principle of Plato's cosmology, the creative or "self-moving" capacity of mind or "soul" as such, in terms of which, infinitely more easily than was possible in Plato's time, we can explain the active singularities hidden under the appearance of inert masses from which the idea of mere matter has always been an illegitimate inference.

One final point: Many dualists have followed Descartes in denying the extendedness of mind. Peirce, like James, Clifford, Whitehead, and some others, several of them expert in geometry, have asserted that mind is extended. Peirce is not as clear as one wishes about the analysis of space, in one place saying that, as time gives the possibility of one subject having incompatible predicates, so space gives the possibility of many subjects having one and the same predicate. This is a substance account of "subject" and of space. But he also gives some indication of the more analytic event account. In reality time is the way there are *asymmetrical* dynamic relations, causal conditions being earlier and results later: space is the way there are *symmetrical* dynamic relations, either of mutual independence, as of contemporary events, or of mutual interdependence, as of contemporary substances near enough in proportion to the endurance of their careers to have effects upon one another.¹⁴ Relativity physics has, for the first time in the history of philosophy, decisively clarified this matter. There is nothing in the notion of space as now employed in science to prevent instances of mind from having spatial relations, provided they can mutually influence each other under some conditions and be without such influence under others. The notion that everything spatial has shape in the manner in which sticks and stones and other aggregates do, or the atoms of the Greek atomists, in this age of radiation and electrons ought to be dismissed along with some other primitive crudities.

Peirce was largely free from these. And by his doctrine of Secondness and of the direct sympathy of mind with mind (agapism) he escaped in

principle from the trouble Leibniz had in explaining, or explaining away, space. It was not at all because Leibniz attributed perceptions to all singulars (monads) that he denied their capacity to act or undergo action (the famous "no windows" doctrine), but rather because in effect he denied perception altogether. Monads did not experience their neighbors, which is what it means to have perception; rather they experienced their own experiences, their own images, which only by virtue of the divinely chosen pre-established harmony had anything to do with those of their neighbors. This is a doctrine of pseudoperceptions and is about as far from good sense as the current tendency to deny that we have experiences, as distinct from mere bodily behaviors. "My neighbor," said Peirce, "is he with whom I intimately react." Well, if sentient creatures (taken as event "societies" or sequences) mutually experience one another, then of course they interact, for this is only an aspect of the very same relation, or tissue of relations. Mind of its own resources can supply all that is needed for spatio-temporal (symmetrical-asymmetrical-dynamic) order. Adding "matter" contributes no additional information.

Peirce was not far from, but did not quite achieve, the "scientific metaphysics" which he predicted for this century.

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NOTES

1. For Maxwell's views on determinism see *The Life of James Clerk Maxwell*. Ed. Lewis Campbell and W. Garnett (London: Macmillan & Co., 1884. pp. 363-66. Also *The Collected Scientific Papers of James Clerk Maxwell*. Ed. W. J. Niven (Cambridge University Press, 1890). Vol. II, p. 760.

For Peirce's "tychistic" view of causation see *The Collected Papers of Charles S. Peirce*. Ed. C. Hartshorne, P. Weiss, and A. Burks (Cambridge, Mass.: Harvard University Press, 1931-1958).

2. Emile Boutroux, *De la Contingence des lois de la nature*. (Paris, 1874).

3. Peirce, *op. cit.*, 1.170.

4. *Ibid.*, 4.172. "It is only actuality . . . which bursts the fluidity of the general and produces a discrete unit." See also 6.169-72.

5. *Ibid.*, 4.68. I regard this as the best, or at any rate the most fully generalized, definition of nominalism and realism.

6. A. N. Whitehead, *Process and Reality* (New York: Macmillan, 1929), Pt. II, Ch. II, Secs. II, IV, V; Pt. IV, Ch. I, Sec. I. Also *Science and the Modern World* (New York: Macmillan, 1925), last 4 pp. of Ch. VII, also Ch. VIII. Von

Wright's argument against continuous becoming differs from Whitehead's (which he does not mention) and is perhaps more cogent. See G. H. von Wright's Eddington Memorial Lecture, *Time, Change and Contradiction* (Cambridge University Press, 1968).

7. Peirce, *op. cit.*, 7.352.

8. *Op. cit.*, 1.169, 7.653.

9. *Ibid.*, 7.547.

10. Sir Karl Popper has derived the Uncertainty Principle from the original formula of Max Planck for quantum discontinuity, without any reference to difficulties of measurement. According to Popper, the issue turns on the indispensability of statistical laws in dealing with certain phenomena and of their irreducibility (demonstrated by him, also by A. Landé) to deterministic laws. See Popper's *Objective Knowledge: an Evolutionary View* (Oxford: Clarendon Press, 1972), pp. 303f. See also p. 215.

11. Peirce, *op. cit.*, 2.339; 3.93, 216, 612; 8.208.

12. E. Schroedinger, *Science and Humanism* (Cambridge University Press, 1951), pp. 51ff. K. Popper, *op. cit.*, pp. 141f., 303, 306.

13. Schroedinger, *What is Life?* (Cambridge University Press, 1951), pp. 88-92. Also *Was ist ein Naturgesetz?* (Munich, Vienna: Oldenbourg, 1962), pp. 73-85. That reality consists of events not things is argued in *Science and Humanism*, pp. 18-29, 43-47, and in *Was ist ein Naturgesetz*, pp. 115-119, 129-143.

14. C. Hartshorne, *Creative Synthesis and Philosophic Method* (London, La Salle: SCM Press, Open Court Pub. Co., 1970).