The Ways of Paradox

and Other Essays

REVISED AND ENLARGED EDITION

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Harvard University Press
Cambridge, Massachusetts
and London, England
1976

Printed in the United States of America

Library of Congress Catalog Card Number 76-4200

ISBN 0-674-94835-1 (cloth)
ISBN 0-674-94837-8 (paper)

To my daughter

Margaret

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Posits and Reality

I. SUBVISIBLE PARTICLES

According to physics my desk is, for all its seeming fixity and solidity, a swarm of vibrating molecules. The desk as we sense it is comparable to a distant haystack in which we cannot distinguish the individual stalks; comparable also to a wheel in which, because of its rapid rotation, we cannot distinguish the individual spokes. Comparable, but with a difference. By approaching the haystack we can distinguish the stalks, and by retarding the wheel we can distinguish the spokes. On the other hand no glimpse is to be had of the separate molecules of the desk; they are, we are told, too small.

Lacking such experience, what evidence can the physicist muster for his doctrine of molecules? His answer is that there is a convergence of indirect evidence, drawn from such varied phenomena as expansion, heat conduction, capillary attraction, and surface tension. The point is that these miscellaneous phenomena can, if we assume the molecular theory, be marshaled under the familiar laws of motion. The fancifulness of thus assuming a substructure of moving particles of imperceptible size is offset by a gain in naturalness and scope on the part of the aggregate laws

Written about 1955 for the beginning of *Word and Object*, but eventually superseded. First published along with a Japanese translation in S. Uyeda, ed., *Basis of the Contemporary Philosophy*, Vol. 5 (Tokyo: Waseda University Press, 1960). It has appeared also in Italian, *Rivista di Filosofia*, 1964.

of physics. The molecular theory is felt, moreover, to gain corroboration progressively as the physicist's predictions of future observations turn out to be fulfilled, and as the theory proves to invite extensions covering additional classes of phenomena.

The benefits thus credited to the molecular doctrine may be divided into five. One is simplicity: empirical laws concerning seemingly dissimilar phenomena are integrated into a compact and unitary theory. Another is familiarity of principle: the already familiar laws of motion are made to serve where independent laws would otherwise have been needed. A third is scope: the resulting unitary theory implies a wider array of testable consequences than any likely accumulation of separate laws would have implied. A fourth is fecundity: successful further extensions of theory are expedited. The fifth goes without saying: such testable consequences of the theory as have been tested have turned out well, aside from such sparse exceptions as may in good conscience be chalked up to unexplained interferences.

Simplicity, the first of the listed benefits, is a vague business. We may be fairly sure of this much: theories are more or less simple, more or less unitary, only relative to one or another given vocabulary or conceptual apparatus. Simplicity is, if not quite subjective, at any rate parochial. Yet simplicity contributes to scope, as follows. An empirical theory, typically, generalizes or extrapolates from sample data, and thus covers more phenomena than have been checked. Simplicity, by our lights, is what guides our extrapolation. Hence the simpler the theory, on the whole, the wider this unchecked coverage.

As for the fourth benefit, fecundity, obviously it is a consequence of the first two, simplicity and familiarity, for these two traits are the best conditions for effective thinking.

Not all the listed benefits are generally attributable to accepted scientific theories, though all are to be prized when available. Thus the benefit of familiarity of principle may, as in quantum theory and relativity theory, be renounced, its loss being regretted but outweighed.

But to get back. In its manifest content the molecular doctrine bears directly on unobservable reality, affirming a structure of

minute swarming particles. On the other hand any defense of it has to do rather with its indirect bearing on observable reality. The doctrine has this indirect bearing by being the core of an integrated physical theory which implies truths about expansion, conduction, and so on. The benefits which we have been surveying are benefits which the molecular doctrine, as core, brings to the physics of these latter observable phenomena.

Suppose now we were to excise that core but retain the surrounding ring of derivative laws, thus not disturbing the observable consequences. The retained laws could be viewed thenceforward as autonomous empirical laws, innocent of any molecular commitment. Granted, this combination of empirical laws would never have been achieved without the unifying aid of a molecular doctrine at the center; note the recent remarks on scope. But we might still delete the molecular doctrine once it has thus served its heuristic purpose.

This reflection strengthens a natural suspicion: that the benefits conferred by the molecular doctrine give the physicist good reason to prize it, but afford no evidence of its truth. Though the doctrine succeed to perfection in its indirect bearing on observable reality, the question of its truth has to do rather with its direct claim on unobservable reality. Might the molecular doctrine not be ever so useful in organizing and extending our knowledge of the behavior of observable things, and yet be factually false?

One may question, on closer consideration, whether this is really an intelligible possibility. Let us reflect upon our words and how we learned them.

II. POSITS AND ANALOGIES

Words are human artifacts, meaningless save as our associating them with experience endows them with meaning. The word 'swarm' is initially meaningful to us through association with such experiences as that of a hovering swarm of gnats, or a swarm of dust motes in a shaft of sunlight. When we extend the word to desks and the like, we are engaged in drawing an analogy between swarms ordinarily so-called, on the one hand, and desks,

etc., on the other. The word 'molecule' is then given meaning derivatively: having conceived of desks analogically as swarms, we imagine molecules as the things the desks are swarms of.

The purported question of fact, the question whether the familiar objects around us are really swarms of subvisible particles in vibration, now begins to waver and dissolve. If the words involved here make sense only by analogy, then the only question of fact is the question how good an analogy there is between the behavior of a desk or the like and the behavior, e.g., of a swarm of gnats. What had seemed a direct bearing of the molecular doctrine upon reality has now dwindled to an analogy.

Even this analogical content, moreover, is incidental, variable, and at length dispensable. In particular the analogy between the swarming of the molecules of a solid and the swarming of gnats is only moderately faithful; a supplementary aid to appreciating the dynamics of the molecules of a solid is found in the analogy of a stack of bedsprings. In another and more recondite part of physics, the theory of light, the tenuousness of analogy is notorious: the analogy of particles is useful up to a point and the analogy of waves is useful up to a point, but neither suffices to the exclusion of the other. Faithful analogies are an aid to the physicist's early progress in an unaccustomed medium, but, like water-wings, they are an aid which he learns to get along without.

In §I we contrasted a direct and an indirect bearing of the molecular doctrine upon reality. But the direct bearing has not withstood scrutiny. Where there had at first seemed to be an undecidable question of unobservable fact, we now find mere analogy at most and not necessarily that. So the only way in which we now find the molecular doctrine genuinely to bear upon reality is the indirect way, via implications in observable phenomena.

The effect of this conclusion upon the status of molecules is that they lose even the dignity of inferred or hypothetical entities which may or may not really be there. The very sentences which seem to propound them and treat of them are gibberish by themselves, and indirectly significant only as contributory clauses of an inclusive system which does also treat of the real. The molecular physicist is, like all of us, concerned with commonplace reality, and merely finds that he can simplify his

laws by positing an esoteric supplement to the exoteric universe. He can devise simpler laws for this enriched universe, this "sesquiverse" of his own decree, than he has been able to devise for its real or original portion alone.

In §I we imagined deleting the molecular doctrine from the midst of the derivative body of physical theory. From our present vantage point, however, we see that operation as insignificant; there is no substantive doctrine of molecules to delete. The sentences which seem to propound molecules are just devices for organizing the significant sentences of physical theory. No matter if physics makes molecules or other insensible particles seem more fundamental than the objects of common sense; the particles are posited for the sake of a simple physics.

The tendency of our own reflections has been, conversely, to belittle molecules and their ilk, leaving common-sense bodies supreme. Still, it may now be protested, this invidious contrast is unwarranted. What are given in sensation are variformed and varicolored visual patches, varitextured and varitemperatured tactual feels, and an assortment of tones, tastes, smells, and other odds and ends; desks are no more to be found among these data than molecules. If we have evidence for the existence of the bodies of common sense, we have it only in the way in which we may be said to have evidence for the existence of molecules. The positing of either sort of body is good science insofar merely as it helps us formulate our laws—laws whose ultimate evidence lies in the sense data of the past, and whose ultimate vindication lies in anticipation of sense data of the future. The positing of molecules differs from the positing of the bodies of common sense mainly in degree of sophistication. In whatever sense the molecules in my desk are unreal and a figment of the imagination of the scientist, in that sense the desk itself is unreal and a figment of the imagination of the race.

This double verdict of unreality leaves us nothing, evidently, but the raw sense data themselves. It leaves each of us, indeed, nothing but his own sense data; for the assumption of there being other persons has no better support than has the assumption of there being any other sorts of external objects. It leaves each of us in the position of solipsism, according to which there is nobody else in the world, nor indeed any world but the pageant of one's own sense data.

III. RESTITUTION

Surely now we have been caught up in a wrong line of reasoning. Not only is the conclusion bizarre; it vitiates the very considerations that lead to it. We cannot properly represent man as inventing a myth of physical objects to fit past and present sense data, for past ones are lost except to memory; and memory, far from being a straightforward register of past sense data, usually depends on past posits of physical objects. The positing of physical objects must be seen not as an *ex post facto* systematization of data, but as a move prior to which no appreciable data would be available to systematize.

Something went wrong with our standard of reality. We became doubtful of the reality of molecules because the physicist's statement that there are molecules took on the aspect of a mere technical convenience in smoothing the laws of physics. Next we noted that common-sense bodies are epistemologically much on a par with the molecules, and inferred the unreality of the common-sense bodies themselves. Here our bemusement becomes visible. Unless we change meanings in midstream, the familiar bodies around us are as real as can be; and it smacks of a contradiction in terms to conclude otherwise. Having noted that man has no evidence for the existence of bodies beyond the fact that their assumption helps him organize experience, we should have done well, instead of disclaiming evidence for the existence of bodies, to conclude: such, then, at bottom, is what evidence is, both for ordinary bodies and for molecules.

This point about evidence does not upset the evidential priority of sense data. On the contrary, the point about evidence is precisely that the testimony of the senses *does* (contrary to Berkeley's notion) count as evidence for bodies, such being (as Samuel Johnson perceived) just the sort of thing that evidence is. We can continue to recognize, as in §II, that molecules and even the gross bodies of common sense are simply posited in the course of organizing our responses to stimulation; but a moral to draw from our reconsideration of the terms 'reality' and 'evidence' is that posits are not *ipso facto* unreal. The benefits of the molecular doctrine which so impressed us in §I, and the manifest benefits of the aboriginal posit of ordinary bodies, are the best

evidence of reality we can ask (pending, of course, evidence of the same sort for some alternative ontology).

Sense data are posits too. They are posits of psychological theory, but not, on that account, unreal. The sense datum may be construed as a hypothetical component of subjective experience standing in closest possible correspondence to the experimentally measurable conditions of physical stimulation of the end organs. In seeking to isolate sense data we engage in empirical psychology, associating physical stimuli with human resources. I shall not guess how useful the positing of sense data may be for psychological theory, or more specifically for a psychologically grounded theory of evidence, nor what detailed traits may profitably be postulated concerning them. In our flight from the fictitious to the real, in any event, we have come full circle.

Sense data, if they are to be posited at all, are fundamental in one respect; the small particles of physics are fundamental in a second respect, and common-sense bodies in a third. Sense data are *evidentially* fundamental: every man is beholden to his senses for every hint of bodies. The physical particles are *naturally* fundamental, in this kind of way: laws of behavior of those particles afford, so far as we know, the simplest formulation of a general theory of what happens. Common-sense bodies, finally, are *conceptually* fundamental: it is by reference to them that the very notions of reality and evidence are acquired, and that the concepts which have to do with physical particles or even with sense data tend to be framed and phrased. But these three types of priority must not be viewed as somehow determining three competing, self-sufficient conceptual schemes. Our one serious conceptual scheme is the inclusive, evolving one of science, which we inherit and, in our several small ways, help to improve.

IV. WORKING FROM WITHIN

It is by thinking within this unitary conceptual scheme itself, thinking about the processes of the physical world, that we come to appreciate that the world can be evidenced only through stimulation of our senses. It is by thinking within the same conceptual scheme that we come to appreciate that language, being a social art, is learned primarily with reference to intersubjectively conspicuous objects, and hence that such objects are bound to be central conceptually. Both of these *aperçus* are part of the scientific understanding of the scientific enterprise; not prior to it. Insofar as they help the scientist to proceed more knowingly about his business, science is using its findings to improve its own techniques. Epistemology, on this view, is not logically prior somehow to common sense or to the refined common sense which is science; it is part rather of the overall scientific enterprise, an enterprise which Neurath has likened to that of rebuilding a ship while staying afloat in it.

Epistemology, so conceived, continues to probe the sensory evidence for discourse about the world; but it no longer seeks to relate such discourse somehow to an imaginary and impossible sense-datum language. Rather it faces the fact that society teaches us our physicalistic language by training us to associate various physicalistic sentences directly, in multifarious ways, with irritations of our sensory surfaces, and by training us also to associate various such sentences with one another.

The complex totality of such associations is a fluctuating field of force. Some sentences about bodies are, for one person or for many, firmly conditioned one by one to sensory stimulation of specifiable sorts. Roughly specifiable sequences of nerve hits can confirm us in statements about having had breakfast, or there being a brick house on Elm Street, beyond the power of secondary associations with other sentences to add or detract. But there is in this respect a grading-off from one example to another. Many sentences even about common-sense bodies rest wholly on indirect evidence; witness the statement that one of the pennies now in my pocket was in my pocket last week. Conversely, sentences even about electrons are sometimes directly conditioned to sensory stimulation, e.g., via the cloud chamber. The status of a given sentence, in point of direct or indirect connection with the senses, can change as one's experience accumulates; thus a man's first confrontation with a cloud chamber may forge a direct sensory link to some sentences which hitherto bore, for him, only the most indirect sensory relevance. Moreover the sensory relevance of sentences will differ widely from person to person; uniformity comes only where the pressure for communication comes.

Statements about bodies, common-sense or recondite, thus commonly make little or no empirical sense except as bits of a collectively significant containing system. Various statements can surely be supplanted by their negations, without conflict with any possible sensory contingency, provided that we revise other portions of our science in compensatory ways. Science is empirically underdetermined: there is slack. What can be said about the hypothetical particles of physics is underdetermined by what can be said about sensible bodies, and what can be said about these is underdetermined by the stimulation of our surfaces. An inkling of this circumstance has doubtless fostered the tendency to look upon the hypothetical particles of physics as more of a fiction than sensible bodies, and these as more of a fiction than sense data. But the tendency is a perverse one, for it ascribes full reality only to a domain of objects for which there is no autonomous system of discourse at all.

Better simply to explore, realistically, the less-than-rigid connections that obtain between sensory stimulus and physical doctrine, without viewing this want of rigidity as impugning the physical doctrine. Benefits of the sort recounted in §I are what count for the molecular doctrine or any, and we can hope for no surer touchstone of reality. We can hope to improve our physics by seeking the same sorts of benefits in fuller measure, and we may even facilitate such endeavors by better understanding the degrees of freedom that prevail between stimulatory evidence and physical doctrine. But as a medium for such epistemological inquiry we can choose no better than the selfsame world theory which we are trying to improve, this being the best available at the time.

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On Simple Theories of a Complex World

It is not to be wondered that theory makers seek simplicity. When two theories are equally defensible on other counts, certainly the simpler of the two is to be preferred on the score of both beauty and convenience. But what is remarkable is that the simpler of two theories is generally regarded not only as the more desirable but also as the more probable. If two theories conform equally to past observations, the simpler of the two is seen as standing the better chance of confirmation in future observations. Such is the maxim of the simplicity of nature. It seems to be implicitly assumed in every extrapolation and interpolation, every drawing of a smooth curve through plotted points. And the maxim of the uniformity of nature is of a piece with it, uniformity being a species of simplicity.

Simplicity is not easy to define. But it may be expected, whatever it is, to be relative to the texture of a conceptual scheme. If the basic concepts of one conceptual schema are the derivative concepts of another, and vice versa, presumably one of two hypotheses could count as simpler for the one scheme and the other for the other. This being so, how can simplicity carry any peculiar presumption of objective truth? Such is the implausibility of the maxim of the simplicity of nature.

Written in 1960 for J. H. Woodger's seventieth birthday. In company with other such papers, it appeared in *Synthese* (Volume 15, 1963), and afterward in J. R. Gregg and F. T. C. Harris, eds., *Form and Strategy in Science* (Dordrecht, Holland: D. Reidel Publishing Co., 1964).