THE QUEST FOR CERTAINTY

A STUDY OF THE RELATION OF KNOWLEDGE AND ACTION

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CHAPTER V

IDEAS AT WORK

Of all philosophical problems that which concerns the nature and worth of ideas is probably the one that most readily appeals to any cultivated mind. The eulogistic flavour which hangs about the word Idealism is a tribute to the respect men pay to thought and its power. The obnoxious quality of materialism is due to its depression of thought, which is treated as an illusion or at most an accidental by-product; materialism leaves no place where ideas have creative or regulative effect. In some sense the cause of ideas, of thought, is felt to be that of the distinctive dignity of man himself. Serious minds have always desired a world in which experiences would be productive of ideas, of meanings, and in which these ideas in turn would regulate conduct. Take away ideas and what follows from them and man seems no better than the beasts of the field.

It is, however, an old story that philosophers have divided into opposed schools as to the nature of ideas and their power. To the extreme right are those who, under the banner of Idealism, have asserted that thought is the creator of the universe and that rational ideas constitute its structure. This constitutive work, however, is something done once for all by thought in a transcendental aboriginal work. The empirical world in which we live from day by day is crass and obdurate, stubbornly un-ideal in character because it is only an appearance of the reality of which thought is the author. This philosophic mode of paying reverence to ideas is thus compensatory rather than vital. It has nothing to do with rendering the natural and social environment of our experience a more ideal abode, namely, one characterized by meanings which are the fruits of thought. There are those who would be willing to exchange the thought which constitutes reality once for all for that thinking which by continued particular acts renders our experienced world here and now more charged with coherent and luminous meanings.

At the other pole is the school of sensational empiricists who hold that the doctrine that thought in any mode of operation is originative is an illusion. It proclaims the necessity of direct, first-hand contact with things as the source of all knowledge. Ideas are pale ghosts of flesh-and-blood impressions; they are images, pallid reflections, dying echoes of first-hand intercourse with reality which takes place in sensation alone.

In spite of the polar opposition between the two schools, they depend upon a common premise. According to both systems of philosophy, *reflective* thought, thinking that involves inference and judgment, is not originative. It has its test in antecedent reality as that is disclosed in some non-reflective immediate knowledge. Its validity depends upon the possibility of checking its conclusions by identification with the terms of such prior immediate knowledge. The controversy between the schools is simply as to the organ and nature of previous direct knowledge. To both schools, reflection, thought involving inference, is *re*productive; the "proof" of its results is found in comparison with what is known without any inference. In traditional empiricism the test is found in sensory impressions. For objective idealism, reflective inquiry is valid only as it reproduces the work previously effected by constitutive thought. The goal of human thinking is approximation to the reality already instituted by absolute reason. The basic premise is also shared by realists. The essence of their position is that reflective inquiry is valid as it terminates in apprehension of that which already exists. When thinking introduces any modification into antecedent reality it falls into error; in fact, productive origination on the part of mind defines error.

The issue is connected with the analysis of experimental knowing which was begun in the preceding chapter. For the common premise of these philosophical schools, so opposed to one another in most ways, goes back to adoption of the idea about knowledge in relation to what is independently real which, originating in Greek thought, has become engrained in tradition. In our summary of the characteristics of experimental thinking, its second trait was said to be the direction of experiment by ideas, the fact that experiment is not random, aimless action, but always includes, along with groping and relatively blind doing, an element of deliberate foresight and intent, which determines that one operation rather than another be tried. In this chapter we shall, accordingly, consider the implications for the theory of ideas that follow from experimental method. Let us suppose, for the time being, that all that we can know about ideas is derived from the way in which they figure in the reflective inquiries of science. What conception of their nature and office shall we then be led to form?

We shall begin, somewhat abruptly, with a statement of the nature of conceptions which has been framed on the basis of recent conclusions in physical science. We shall then compare this idea about ideas with that which was embodied in the Newtonian philosophy of nature and science, and take up the reasons which compelled the abandonment of the latter. Finally we shall recur to a comparison of the result reached with the doctrine embodied in traditional philosophies—one that is identical with that found in the now discredited Newtonian natural philosophy.

The position of present science on this matter has been stated as follows: "To find the length of an object, we have to perform certain physical operations. The concept of length is therefore fixed when the operations by which length is measured are fixed; that is, the concept of length involves as much as and nothing more than the set of operations by which length is determined. In general, we mean by any concept nothing more than a set of operations; *the concept is synonymous with the corresponding set of operations*."[1] The same idea is

[1] Bridgman, *The Logic of Modern Physics*, New York, 1927, p. 5. The italics are in the text.

repeated by Eddington in his Gifford Lectures. His statement is as follows: "The vocabulary of the physicist comprises a number of words such as length, angle, velocity, force, potential, current, etc., which we call 'physical quantities'. It is now recognized that these should be *defined* according to the way in which we recognize them when actually confronted with them, and not according to the metaphysical significance which we may have anticipated for them. In the old text-books mass was defined as 'quantity of matter'; but when it came to an actual determination of mass, an experimental method was prescribed which had no bearing on this definition."[1] The adoption of this point of view with respect to the meaning and content of thinking, and as to the validity or soundness of the ideas by means of which we understand natural events, makes possible what has been lacking throughout the history of thought, a genuinely experimental empiricism. The phrase "experimental empiricism" sounds redundant. It ought to be so in fact, since the adjective and the noun should have the

[1] *The Nature of the Physical World*, London and New York, 1928, p. 255. It is implied in the quotation that concepts are recognized by means of the experimental operations by which they are determined; that is, operations define and test the validity of the meanings by which we state natural happenings. This implication is made explicit a few sentences further along, when in speaking of Einstein Mr. Eddington says his theory "insists that each physical quantity should be defined as the result of certain operations of measurement and calculation". The principle is anticipated in Peirce's essay on *How to Make Our Ideas Clear*, published as far back as 1881—now reprinted in a volume of essays, edited by Morris R. Cohen, and entitled *Chance, Love and Logic*, New York, 1923. Peirce states that the sole meaning of the idea of an object consists of the consequences which result when the object is acted upon in a particular way. The principle is one element in the pragmatism of James. The idea is also akin to the "instrumental" theory of conceptions, according to which they are intellectual instruments for directing our activities in relation to existence. The principle of "extensive abstraction" as a mode of defining things is similar in import. On account of ambiguities in the notion of pragmatism—although its *logical* import is identical—I shall follow Bridgman in speaking of "operational thinking".

same significance, so that nothing is gained by using the two terms. But historically such is not the case. For, historically, empirical philosophies have been framed in terms of sensations or sense data. These have been said to be the material out of which ideas are framed and by agreement with which they are to be tested. Sensory qualities are the antecedent models with which ideas must agree if they are to be sound or "proved".[1] These doctrines have always evoked an abundance of criticisms. But the criticisms have taken the form of depreciating the capacity of "experience" to provide the source and test of our fundamentally important ideas in either knowledge or morals. They have used the weaknesses of sensational empiricism to reinforce the notion that ideas are framed by reason apart from any experience whatsoever; to support what is known in the vocabulary of philosophical systems as an *a priori* rationalism.

From the standpoint of the operational definition and tests of ideas, ideas have an empirical origin and status. But it is that of *acts* performed, acts in the literal and existential sense of the word, deeds done, not reception of sensations forced on us from without. Sensory qualities are important. But they are intellectually significant only as consequences of acts intentionally performed. A colour seen at a particular locus in a spectral band is, for example, of immense intellectual importance in chemistry and in astro-physics. But *merely* as seen, as a bare sensory quality, it is the same for the clodhopper and the scientist; in either case, it is the product of a direct sensory excitation; it is just and only another colour the eye has happened upon. To suppose that its cognitive value can be eked out or supplied by associating it with other sensory qualities of the same nature as itself, is like supposing that by

[1] The whole empirical logic of Mill professedly, and as far as consistent with itself, is an endeavour to show that all propositions involving reflection and ideas must be proved, or demonstrated to be true, by reduction to propositions consisting only of material directly given in sensation.

putting a pile of sand in the eye we can get rid of the irritation caused by a single grain. To suppose, on the other hand, that we must appeal to a synthetic activity of an independent thought to give the quality meaning in and for knowledge, is like supposing that by thinking in our heads we can convert a pile of bricks into a building. Thinking, carried on inside the head, can make some headway in forming the *plan* of a building. But it takes actual operations to which the plan, as the fruit of thought, gives instrumental guidance to make a building out of separate bricks, or to transform an isolated sensory quality into a significant clue to knowledge of nature.

Sensory qualities experienced through vision have their cognitive status and office, not (as sensational empiricism holds) in and of themselves in isolation, or as merely forced upon attention, but because they are the consequences of definite and intentionally performed operations. Only in connection with the intent, or idea, of these operations do they amount to anything, either as disclosing any fact or giving test and proof of any theory. The rationalist school was right in as far as it insisted that sensory qualities are significant for knowledge only when connected by means of ideas. But they were wrong in locating the connecting ideas in intellect apart from experience. Connection is instituted through operations which define ideas, and operations are as much matters of experience as are sensory qualities.

It is not too much to say, therefore, that for the first time there is made possible an empirical theory of ideas free from the burdens imposed alike by sensationalism and *a priori* rationalism. This accomplishment is, I make bold to say, one of three or four outstanding feats of intellectual history. For it emancipates us from the supposed need of always harking back to what has already been given, something had by alleged direct or immediate knowledge in the past, for the test of the value of ideas. A definition of the nature of ideas in terms of operations to be performed and the test of the validity of the ideas by the *consequences* of these operations establishes connectivity within concrete experience. At the same time, by emancipation of thinking from the necessity of testing its conclusions solely by reference to antecedent existence it makes clear the originative possibilities of thinking.

John Locke has always been the central figure in the empirical school. With extraordinary thoroughness he laid the foundations of that empirical logic which tests the validity of every belief about natural existence by the possibility of resolving the content of the belief into simple ideas originally received through the senses. If we want to know what "solidity" or any other idea is, we are, in his own words, "sent to the senses". In developing this theory of the origin and test of our natural knowledge (for he excepted mathematical and moral ideas) he found himself building upon the foundation laid by his illustrious contemporary, Sir Isaac Newton. The latter was convinced of the unsoundness of the rationalistic philosophy of science represented by Descartes, for a time the great rival of Newton for supremacy in the scientific world. Newton's own use of mathematics and also his conception of gravitation (with some other of his physical ideas) exposed him, however, to the charge of reviving the "occult essences" of scholasticism. Accordingly, he was very emphatic upon the point that he was thoroughly empirical in premises, method and conclusions; empirical in that he had gone to his senses and taken what he found there as the origin and justification of his primary scientific ideas about nature. As we shall see, certain assumptions of Newton were in fact far from empirical in any experimental sense of that word, but were introduced by him into the philosophical foundations of natural science and were thence taken over into the whole philosophic theory of science to be questioned only in our own day.

No saying of Newton's is more widely known than that "I do not invent hypotheses". This is only his negative way of asserting complete reliance upon a subject-matter guaranteed by the senses—which in turn signifies, as we have just said, that all scientific ideas go *back* to sense-perceptions previously had for both their origin and their warrant. We shall consider first the effect of Newton's procedure upon the supposed foundations of natural science, and then consider how the recognition of an operational—and relational—definition of scientific conceptions instead of a discrete and sensory one has destroyed those foundations.

While Newton employed mathematical conceptions with a freedom equal to that of Descartes and with a heuristic power far exceeding Descartes, he differentiated his own method from that of the latter by insisting that the objects to which his mathematical calculations applied were not products of thought, but were given, as far as the properties which figured in his science were concerned, in sense. That is, he did not claim that he could sensibly observe the ultimate particles or atoms which were the foundation of his system, but he did claim that he had sensible grounds for assuming their existence, and especially he insisted that all the properties with which his scientific theory endowed these particles were derived from and were verifiable in direct sense-perception. In his own words: "Whatever is not derived from phenomena is to be called a hypothesis, and hypotheses . . . have no place in experimental philosophy." The positive counterpart of this negative statement is as follows: "The qualities of bodies which admit of neither intension nor remission of degree and which are found to belong to all bodies within the reach of experiments, are to be assumed the universal qualities of all bodies whatsoever."

Newton's assumption that he was only extending to the ultimate proper objects of physical science those qualities of experienced objects that are disclosed in direct perception is made evident by such passages as the following: "We no other way know the extension of bodies than by our senses, nor do these reach it in all bodies. But because we perceive extension in all bodies that are sensible, therefore we ascribe it universally to all others also. That abundance of bodies are hard, we learn by experience; and because the hardness of the whole arises from the hardness of the parts, we therefore justly infer the hardness of the undivided particles not only of the bodies we feel but of all others. That all bodies are impenetrable we gather not from reason but from sensation. . . . That all bodies are movable and are endued with certain powers (which we call the *vires inertiae*) of persevering in their motion or in their rest we only infer from like properties observed in the bodies that we have seen." Or as Newton says of his "principles", summing it all up: "I consider them not as occult qualities but as general laws of nature . . . their truth *appearing to us by phenomena*." The principles in question were mass, gravity, hardness, impenetrability, extension, motion, inertia, etc.

The essential point of his argument is that non-sensible bodies, namely, the ultimate particles to which mathematical reasoning applies, are endowed with no properties save those which are found by experience to belong to all bodies of which we do have sensible experience. The static (spatial extension, volume) qualities, and the dynamic properties (resistance, perseverance in motion) of ultimate physical realities, are homogeneous with the common qualities of sensibly perceived things. Colour, sound, heat, odour, etc., go out, since they permit of absence, and of remission and increase of degrees—or are not universally present. Volume, mass, inertia, motion and movability, remain as universal qualities. What would happen if some raised the objection that the existence of the ultimate particles is hypothetical, since they are not observed? What becomes of his empiricism even if the properties ascribed to particles are all sensibly verified, provided the bearers of these properties are not observed? It can hardly be said that Newton explicitly discusses this question. It seemed to him practically self-evident that since sensible bodies were divisible without losing the properties that form his "principles", we are entitled to assume the existence of certain last particles of the same kind incapable of further division. And while, in logical consistency, he could hardly have admitted the argument, the fact that he found that he could "explain" actual occurrences on the basis of this assumption seemed to give him ample confirmation of their existence. Perhaps in the following passage he comes as near as anywhere to dealing explicitly with the point. After saying that if *all* particles, all bodies whatever, were capable of being broken, they would then wear away, he goes on to say that in that case the "nature of things depending on them would be changed", and adds "and therefore that *nature may be lasting*, the changes of corporeal things are to be placed only in the various separations and new associations and motions of these permanent particles". "So that nature may be lasting!" It would be hard to find a franker statement of the motive which controlled Newton's doctrine. There was needed some guarantee that Nature would not go to pieces and be dissipated or revert to chaos. How could the unity of anything be secure unless there was something persistent and unchanging behind all change? Without such fixed indissoluble unities, no final certainty was possible. Everything was put in peril of dissolution. These metaphysical fears rather than any experimental evidence determined the nature of the fundamental assumptions of Newton regarding atoms. They furnished the premises which he regarded as scientific and as the very foundations of the possibility of science. "All changes are to be placed in only the separations and new associations of permanent particles." In this statement there is contained a professedly scientific restatement of the old human desire for something fixed as the warrant and object of absolute certainty. Without this fixity knowledge was impossible. Changes are to be known by treating them as indifferent spatial approaches and withdrawals taking place between things that are themselves eternally the same. Thus to establish certainty in existence and in knowledge, "God in the beginning formed matter in solid, massy, hard, impenetrable particles".

It was logically inevitable that as science proceeded on its experimental path it would sooner or later become clear that all conceptions, all intellectual descriptions, must be formulated in terms of operations, actual or imaginatively possible. There are no conceivable ways in which the existence of ultimate unchangeable substances which interact without undergoing change in themselves can be reached by means of experimental operations. Hence they have no empirical, no experimental standing; they are pure dialectic inventions. They were not even necessary for application of the mathematical method of Newton. Most of his analytic work in his *Principles* would remain unchanged if his physical particles were dropped out and geometrical points were substituted. What reason can be assigned for Newton's desertion of an experimental method and for the adoption in its stead of an obviously dialectical conception?—since the conception that the permanence of nature depends upon the assumption of a plurality of discrete immutable substances is clearly dialectical. Doubtless in part the reason was that the scheme worked or seemed to work. Without developing or acknowledging the consequences of this mode of justification, objections based on theory could always be met by pointing to the marvellous conclusions of physical inquiry.

But a more fundamental reason was that the minds of men, including physical inquirers, were still possessed by the old notion that reality in order to be solid and firm must consist of those fixed immutable things which philosophy calls substances. Changes could be *known* only if they could be somehow reduced to recombinations of original unchanging things. For these alone can be objects of certainty—the changing is as such the uncertain—and only the certain and exact is knowledge. Thus a popular metaphysics, given rational formulation by the Greeks, and taken over into the intellectual tradition of the western world, controlled at first the interpretations placed upon the procedures and conclusions of experimental knowing.

This hypothesis as to the origin of the non-experimental factor in the Newtonian philosophy is confirmed by his own use of the metaphysics of the ideas of substance and essential properties. The fact that Newton adopted the Democritean rather than the Aristotelean conception of substance is of course of immense importance scientifically. But philosophically speaking it is of slight import compared with the fact that he followed the supposed necessities of dialectic reasoning rather than the lead of experienced subject-matter in accepting without question the notion that there must be at the foundation of all existence certain things which are intrinsically unchangeable, and that such immutable entities are the objects of any true knowledge because they give the warrant of fixed certitude.

With his acceptance of the old doctrines of substances goes that of the doctrine of essence. If fixed unchangeable things exist, they must have certain inherent, unchangeable properties. Changes are accidental and external; they occur *between* substances and do not affect their inner nature. If they did, substances would not be substances; they would change and rot away. Hence, in spite of starting upon the experimental and mathematical path, Newtonian science kept the idea that atoms are characterized by eternal properties or qualities, that is by essences. Substances are "solid, hard, massy, impenetrable, movable particles". Their essence is precisely these unchangeable, fixed qualities of solidity, mass, motion, inertia.

It thus appears that Newton retained a part of the qualitative equipment of the objects of Greek science, in spite of their irrelevance to both mathematics and experiment. When one searches through philosophical commentary and discussion (based mainly on Locke's version of Newton's results), one finds a great deal of discussion about the fact that the so-called secondary qualities, colour, sound, odour, taste, were eliminated from "reality". But not a word as far as I can discover is said about the fact that *other* sensible qualities under the name of primary were retained in defining the object of science. And yet this retention is the *fons et origo malorum.* The actual fact was that science by means of its operational conceptions was instituting as its objects of thought things in a dimension different from *any* of the direct *qualities* of objects. It was not a question of getting rid of some immediate sense qualities; but of a treatment indifferent to any and all qualities. Newton could not realize this fact, because he insisted that the existence of hard and fixed unchanging substances was the basis of science. Given such substances they had to have some qualities as their inherent properties.

Hence Newton generously endowed them with those properties which he insisted were directly taken from sense experience itself. Consider the consequences for subsequent thought. Getting rid of some qualities which had been regarded as essential to natural things while retaining others did not forward in the least the actual work of science, while it did work inevitably to establish a fixed gulf and opposition between the things of ordinary perception, use and enjoyment and the objects of science which, according to tradition, were the only ultimately "real" objects. The story of the extent to which this opposition became the underlying problem of modern philosophy need not be retold. Nor are we called upon here to consider the way in which it generated an "epistemological" problem of knowledge in the general terms of relation of subject and object, as distinct from the logical problem of the methods by which inquiry shall attain understanding. For qualities expelled from scientific objects were given an asylum "in the mind"; they became mental and psychical in nature, and the problem arose how mind composed of such elements, having nothing in common with objects of science—by doctrinal definition the real things of nature—could possibly reach ou and know their own opposites. In another connection, that result would provide a theme most important to discuss:—

from its origin in Berkeley's contention that since "secondary" qualities are avowedly mental and since primary qualities cannot be disassociated from them, the latter must be mental also, through all the sinuosities of modern thought in dealing with the "problem". But the first of these points, the rivalry of scientific objects and empirical objects for position in natural existence, has already been dealt with and the latter problem is not immediately relevant.

We are here concerned with the Newtonian assumption that we must carry over into the conception and definition of physical objects some of the qualities directly experienced in sense-perception, while their presence in such sense-experience is the warrant or "proof" of their validity as ideas. There was no direct experience of the ultimate massy, hard, impenetrable and indivisible and hence unchangeable particles—since indeed their eternal permanence obviously was a thing incapable of any experience except by some equally eternal mind. Hence these qualities must be *thought*, they must be inferred. In themselves they exist by themselves. But for us, they exist as objects of thought only. Hence as ideas they need a warrant and justification which primary qualities of immediate perception do not need, since these are self-warranting—according to the doctrine.

Now so deeply engrained are the conclusions of the old tradition of rationalism versus (sensationalistic) empiricism, that the question will still be raised: What other certification could be given or can now be given for the properties of scientific physical objects save by inferential extension of the universally found properties of all objects of sense-perception? Is there any alternative unless we are prepared to fall back upon *a priori* rational conceptions supposed to bring their own sufficient authority with them?

It is at this point that the recent recognition that the conceptions by which we think scientific objects are derived neither from sense nor from *a priori* conceptions has its logical and philosophical force. Sense qualities, as we saw in the previous chapter, are something *to be* known, they are challenges to knowing, setting problems for investigation. Our scientific knowledge is something *about* them, resolving the problems they propose. Inquiry proceeds by reflection, by thinking; but *not*, most decidedly, by thinking as conceived in the old tradition, as something cooped up within "mind". For experimental inquiry or thinking signifies *directed activity*, doing something which varies the conditions under which objects are observed and directly had and by instituting new arrangements among them. Things perceived suggest to us (originally just evoke or stimulate) certain ways of responding to them, of treating them. These operations have been continuously refined and elaborated during the history of man on earth, although it is only during the last few centuries that the whole affair of controlled thinking and of its issue in genuine knowledge has been seen to be bound up with their selection and determination.

The central question thus arises: What determines the selection of operations to be performed? There is but one answer:—the nature of the problem to be dealt with—an answer which links the phase of experiment now under discussion with that considered in the last chapter. The first effect of experimental analysis is, as we saw, to reduce objects directly experienced to data. This resolution is required because the objects in their first mode of experience are perplexing, obscure, fragmentary; in some way they fail to answer a need. Given data which locate the nature of the problem, there is evoked a thought of an operation which if put into execution may eventuate in a situation in which the trouble or doubt which evoked inquiry will be resolved. If one were to trace the history of science far enough, one would reach a time in which the acts which dealt with a troublesome situation would be organic responses of a structural type together with a few acquired habits. The most elaborate technique of present inquiry in the laboratory is an extension and refinement of these simple original operations. Its development has for the most part depended upon the utilization of physical instruments, which when inquiry was developed to a certain point were purposely invented. In principle, the history of the construction of suitable operations in the scientific field is not different from that of their evolution in industry. Something needed to be done to accomplish an end; various devices and methods of operation were tried. Experiences of success and failure gradually improved the means used. More economical and effective ways of acting were found—that is, operations which gave the desired kind of result with greater ease, less irrelevancy and less ambiguity, greater security. Each forward step was attended with making better tools. Often the invention of a tool suggested operations not in mind when it was invented and thus carried the perfecting of operations still further. There is thus no *a priori* test or rule for the determination of the operations which define ideas. They are themselves experimentally developed in the course of actual inquiries. They originated in what men naturally do and are tested and improved in the course of doing.

This is as far as the answer to the query can be carried in a formal way. Consequences that successfully solve the problems set by the conditions which give rise to the need of action supply the basis by means of which acts, originally "naturally" performed, become the operations of the art of scientific experimentation. In content, a much more detailed answer can be given. For this answer, one would turn to the historical development of science, in which is recorded what kind of operations have definitely been found to effect the transformation of the obscure and perplexing situations of experience into clear and resolved situations. To go into this matter would be to expound the character of the concepts actually employed in the best developed branches of reflection or inquiry.

While such a discussion is apart from our purpose, there is one common character of all such scientific operations which it is necessary to note. *They are such as disclose relationships.* A simple case is the operation by which length is defined by one object placed end upon end upon another object so many times. This type of operation, repeated under conditions themselves defined by specified operations, not merely fixes the relation of two things to each other called *their* length, but defines a generalized concept of length. This conception in connection with other operations, such as those which define mass and time, become instruments by means of which a multitude of relations between bodies can be established. Thus the conceptions which define units of measurement of space, time and motion become the intellectual instrumentalities by which all sorts of things with no qualitative similarity with one another can be compared and brought within the same system. To the original gross experience of things there is superadded another type of experience, the product of deliberate art, of which *relations* rather than qualities are the significant subject-matter. These connections are as much experienced as are the qualitatively diverse and irreducible objects of original natural experiences.

Qualities present themselves as just what they are, statically demarcated from one another. Moreover, they rarely change, when left to themselves, in such ways as to indicate the interactions or relations upon which their occurrence depends. No one ever observed the production of the thing having the properties of water, nor the mode of generation of a flash of lightning. In sensory perception the qualities are either too static or too abruptly discrete to manifest the specific connections that are involved in their coming into existence. Intentional variation of conditions gives an idea of these connections. Through thought of them the things are understood or truly known. Only slowly, however, did there dawn the full import of the scientific method. For a long time the definitions were supposed to be made not in terms of relations but through certain properties of antecedent things. The space, time and motion of physics were treated as inherent properties of Being, instead of as abstracted relations. In fact, two phases of inquiry accompany each other and correspond to each other. In one of these phases, everything in qualitative objects except their happening is ignored, attention being paid to qualities only as signs of the nature of the particular happening in question: that is, objects are treated as *events*. In the other phase, the aim of inquiry is to correlate events with one another. Scientific conceptions of space, time and motion constitute the generalized system of these correlations of events. Thus they are doubly dependent upon operations of experimental art: upon those which treat qualitative objects as events, and upon those which connect events thus determined with one another.

In these statements we have, however, anticipated the actual movement of scientific thought. This took a long time to arrive at recognition of its own import. Till our own day, scientific conceptions were interpreted in the light of the old belief that conceptions to be valid must correspond to antecedent intrinsic properties resident in objects dealt with. Certain properties regarded by Newton as inherent in substances and essential to them, in independence of connectivity, were indeed speedily seen to be relations. This conversion happened first as to hardness and impenetrability, which were seen to be reducible to mass. *Vis inertiae* was a measure of mass. By careful thinkers "force" was treated as a measure of acceleration and so a name for a relation, not as an inherent property of an isolated thing by virtue of which one thing could compel another to change. Nevertheless, until the promulgation of Einstein's restricted theory of relativity, mass, time and motion were regarded as intrinsic properties of ultimate fixed and independent substances.

We shall postpone till later consideration of the circumstances attending the change. We are here concerned with the fact that when it took place it was, in spite of its upsetting effects upon the foundation of the Newtonian philosophy of science and of nature, from the logical point of view only a clear acknowledgment of what had all the time been the moving principle of the development of scientific method. To say this is not to disparage the scientific importance of the discovery that mass varies with velocity and of the result of the Michelson-Morley experiment on the velocity of light. Such discoveries were doubtless necessary in order to force recognition of the operational or relational character of scientific conceptions. And yet, logically, the way in which space, time and motion, with their various functions, appear in mathematical equations and are translated into equivalent formulations with respect to one another—something which is impossible for qualities as such—indicates that a relational treatment had always been involved. But the imagination of men had become used to ideas framed on the pattern of large masses and relatively slow velocities. It required observation of changes of high velocity, as of light over great distances, and of minute changes occurring at infinitesimal distances to emancipate imagination from its acquired habitudes. The discovery that mass varies with velocity did away with the possibility of continuing to suppose that mass is the defining characteristic of things in isolation from one another—such isolation being the sole condition under which mass could be regarded as immutable or fixed.

The difference made in the actual content of scientific theory is of course enormous. Yet it is not so great as the difference made in the logic of scientific knowledge, nor as in philosophy. With the surrender of unchangeable substances having properties fixed in isolation and unaffected by interactions, must go the notion that certainty is attained by attachment to fixed objects with fixed characters. For not only are no such objects found to exist, but the very nature of experimental method, namely, definition by operations that are interactions, implies that such things are not capable of being known. Henceforth the quest for certainty becomes the search for methods of control; that is, regulation of conditions of change with respect to their consequences.

Theoretical certitude is assimilated to practical certainty; to *security*, trustworthiness of instrumental operations. "Real" things may be as transitory as you please or as lasting in time as you please; these are specific differences like that between a flash of lightning and the history of a mountain range. In any case they are for knowledge "events" not substances. What knowledge is interested in is the correlation among these changes or events—which means in effect that the event called the mountain range must be placed within a system consisting of a vast multitude of included events. When these correlations are discovered, the possibility of control is in our hands. Scientific objects as statements of these inter-relations are instrumentalities of control. They are objects of the *thought* of reality, not disclosures of immanent properties of real substances. They are in particular the thought of reality from a particular point of view: the most highly generalized view of nature as a system of interconnected changes.

Certain important conclusions follow. The test of the validity of ideas undergoes a radical transformation. In the Newtonian scheme, as in the classic tradition, this test resided in properties belonging to ultimate real objects in isolation from one another, and hence fixed or unchanging. According to experimental inquiry, the validity of the object of thought depends upon the *consequences* of the operations which define the object of thought. For example, colours are conceived in terms of certain numbers. The conceptions are valid in the degree in which, by means of these numbers, we can predict future events, and can regulate the interactions of coloured bodies as signs of changes that take place. The numbers are signs or clues of intensity and direction of changes going on. The only things relevant to the question of their validity is whether they are dependable signs. That heat is a mode of motion does not signify that heat and cold as qualitatively experienced are "unreal", but that the qualitative experience can be treated as an event measured in terms of units of velocity of movement, involving units of position and time, so that it can be connected with other events or changes similarly formulated. The test of the validity of any particular intellectual conception, measurement or enumeration is functional, its use in making possible the institution of interactions which yield results in control of actual experiences of observed objects.

In contrast with this fact, in the Newtonian philosophy measurements are important because they were supposed to disclose just how much of a certain property belonged to some body as its own isolated and intrinsic property. Philosophically, the effect of this view was to reduce the "reality" of objects to just such mathematical and mechanical properties—hence the philosophical "problem" of the relation of real physical objects to the objects of experience with their qualities and immediate values of enjoyment and use. Mr. Eddington has said that "the whole of our physical knowledge is based on measures", and that "whenever we state the properties of a body in terms of physical quantities, we are imparting the responses of various metrical indicators to its presence, *and nothing more*".[1] His graphic illustration of the physical formulation of what happens when an elephant slides downhill comes to mind. The mass of the elephant is the reading of a pointer on a weighing scale; the slope of the hill, the reading of a plumb-line against the divisions of a protractor; bulk, a series of readings on the scale of a pair of calipers; colour, readings of a photometer for light; the duration of the slide, a series of readings on a watch-dial, etc.

It seems almost too obvious for mention that a scientific object consisting of a set of measurements of relations between two qualitative objects, and itself accordingly non-qualitative, cannot possibly be taken, or even mis-taken, for a new kind of "real" object which is a rival to the "reality" of the ordinary

[1] *The Nature of the Physical World*, pp. 152 and 257.

object. But so loth are we to surrender traditional conceptions and unwilling as philosophers to surrender as unreal problems which have long engaged attention, that even Mr. Eddington feels called upon to reclothe these scientific measured relations with qualities as something which "mind" mysteriously introduced! Prisoners in jails are often given numbers and are "known" by the numbers assigned. It has not yet occurred to anyone that these numbers are the real prisoners, and that there is always a duplicate real object; one a number, and the other a flesh-and-blood person, and that these two editions of reality have to be reconciled. It is true that the numbers which constitute by means of measurements the object of scientific thought are not assigned so arbitrarily as those of prisoners, but there is no difference in philosophical principle.

Incidentally, Mr. Eddington remarks in his discussion of the metric properties of the object of thought that a knowledge of all possible responses of a concrete thing as measured by suitable devices "would completely determine *its relation to its environment*". The relations a thing sustains are hardly a competitor to the thing itself. Put positively, the physical object, as scientifically defined, is not a duplicated real object, but is a statement, as numerically definite as is possible, of the relations between sets of changes the qualitative object sustains with changes in other things—ideally of all things with which interaction might under any circumstances take place.

Since these correlations are what physical inquiry *does* know, it is fair to conclude that they are what it intends or means to know: on analogy with the legal maxim that any reasonable person intends the reasonably probable consequences of what he does. We come back again to the frequently repeated statement that the problem which has given so much trouble to modern philosophy—that of reconciling the reality of the physical object of science with the richly qualitative object of ordinary experience, is a factitious one. All that is required in order to apprehend that scientific knowledge as a mode of active operation is a potential ally of the modes of action which sustain values in existence, is to surrender the traditional notion that knowledge is possession of the inner nature of things and is the only way in which they may be experienced as they "really" are.

For if one change is correlated definitely with others it can be employed as an indication of their occurrence. Seeing one thing happen we can promptly infer upon what it depends, and what needs to be reinforced or to be weakened if its presence is to be made more secure or is to be done away with. In itself, the object is just what it is experienced as being, hard, heavy, sweet, sonorous, agreeable or tedious and so on. But in being "there" these traits are effects, not causes. They cannot as such be used as means, and when they are set up as ends in view, we are at a loss how to secure them. For just as qualities there are no constant and definite relations which can be ascertained between them and other things. If we wish to regard them not as fixed properties but as things to be attained, we must be able to look upon them as dependent events. If we wish to be able to judge *how* they may be attained, we must connect them as changes with other changes more nearly in our power, until by means of a transitive series of connected changes we arrive at that which we can initiate by our own acts. If one with understanding of the whole situation were to set out to devise means of control of the experience of qualitative values, he would plot a course which would be identical with that followed by experimental science; one in which the results of knowledge would bear the same relation to acts to be performed as do those of actual physical knowledge.

Ability, through a definite or measured correlation of changes, to connect one with another as sign or evidence is the precondition of control. It does not of itself provide direct control; reading the index hand of a barometer as a sign of probable rain does not enable us to stop the coming of the rain. But it does enable us to change our relations to it: to plant a garden, to carry an umbrella on going out, to direct the course of a vessel at sea, etc. It enables *preparatory* acts to be undertaken which make values less insecure. If it does not enable us to regulate just what is to take place, it enables us to direct some phase of it in a way which influences the stability of purposes and results. In other cases, as in the arts proper, we can not only modify our own attitude so as to effect useful preparation for what is to happen, but we can modify the happening itself. This use of one change or perceptible occurrence as a sign of others and as a means of preparing ourselves, did not wait for the development of modern science. It is as old as man himself, being the heart of all intelligence. But accuracy and scope of such judgments, which are the only means with power to direct the course of events and to effect the security of values, depends upon the use of methods such as modern physics has made available.

Extent of control is dependent, as was suggested a moment ago, upon capacity to find a connected series of correlated change, such that each linked pair leads on to another in the direction of a terminal one which can be brought about by our own action. It is this latter condition which is especially fulfilled by the objects of scientific thought. Physical science disregards the qualitative heterogeneity of experienced objects so as to make them all members in one comprehensive homogeneous scheme, and hence capable of translation or conversion one into another. This homogeneity of subject-matter over a broad range of things which are as disparate from each other in direct experience as sound and colour, heat and light, friction and electricity, is the source of the wide and free control of events found in modern technology. Common-sense knowledge can connect things as sign and thing indicated here and there by isolated couples. But it cannot possibly join them all up together so that we can pass from any one to any other. The homogeneity of scientific objects, through formulation in terms of relations of space, time and motion, is precisely the device which makes this indefinitely broad and flexible scheme of transitions possible. The meaning which one event has is translatable into the meanings which others possess. Ideas of objects, formulated in terms of the relations which changes bear to one another, having common measures, institute broad, smooth highways by means of which we can travel from the thought of one part of nature to that of any other. In ideal at least, we can travel from any meaning—or relation—found anywhere in nature to the meaning to be expected anywhere else.

We have only to compare thinking and judging objects in terms of these measured interactions with the classic scheme of a hierarchy of species and genera to see the great gain that has been effected. It is the very nature of fixed kinds to be as exclusive with respect to those of a different order as it is to be inclusive with respect to those which fall within the class. Instead of a thoroughfare from one order to another, there was a sign: No passage. The work of emancipation which was initiated by experimentation, setting objects free from limitation by old habits and customs, reducing them to a collection of data forming a problem for inquiry, is perfected by the method of conceiving and defining objects through operations which have as their consequence accurate metric statements of changes correlated with changes going on elsewhere.

The resolution of objects and nature as a whole into facts stated exclusively in terms of quantities which may be handled in calculation, such as saying that red *is* such a number of changes while green is another, seems strange and puzzling only when we fail to appreciate what it signifies. In reality, it is a declaration that this is the effective way to *think* things; the effective mode in which to frame ideas of them, to formulate their meanings. The procedure does not vary in principle from that by which it is stated that an article is worth so many dollars and cents. The latter statement does not say that the article is literally or in its ultimate "reality" so many dollars and cents; it says that for purpose of exchange that is the way to *think* of it, to judge it. It has many other meanings and these others are usually more important inherently. But *with respect to trade*, it *is* what it is worth, what it will sell for, and the price value put upon it expresses the relation it bears to other things in exchange. The advantage in stating its worth in terms of an abstract measure of exchange such as money, instead of in terms of the amount of corn, potatoes or some other special thing it will exchange for, is that the latter method is restricted and the former generalized. Development of the systems of units by which to measure sensible objects (or form ideas of them) has come along with discovery of the ways in which the greatest amount of free movement from one conception to another is possible.

The formulation of ideas of experienced objects in terms of measured quantities, as these are established by an intentional art or technique, does not say that this is the way they *must* be thought, the *only* valid way of thinking them. It states that for the purpose of generalized, indefinitely extensive translation from one idea to another, this is the way to think them. The statement is like any other statement about instruments, such as that so-and-so is the best way of sending a number of telegraphic dispatches simultaneously. As far as it is actually the best instrumentality, the statement is correct. It has to be proved by *working* better than any other agency; it is in process of continuous revision and improvement. For purposes except that of general and extensive translation of one conception into another, it does not follow that the "scientific" way is the best way of thinking an affair. The nearer we come to an action that is to have an individualized unique object of experience for its conclusion, the less do we think the things in question in these exclusively metric terms. The physician in practice will not think in terms as general and abstract as those of the physiologist in the laboratory, nor the engineer in the field in those as free from special application as will the physicist in his workshop. There are many ways of thinking things in relation to one another;

they are, as conceptions, instruments. The value of an instrument depends upon what is to be done with it. The fine-scale micrometer which is indispensable in the successful performance of one operation would be a hindrance in some other needed act; and a watch-spring is useless to give elasticity to a mattress.

There is something both ridiculous and disconcerting in the way in which men have let themselves be imposed upon, so as to infer that scientific ways of thinking of objects give the inner reality of things, and that they put a mark of spuriousness upon all other ways of thinking of them, and of perceiving and enjoying them. It is ludicrous because these scientific conceptions, like other instruments, are hand-made by man in pursuit of realization of a certain interest—that of the maximum convertibility of every object of thought into any and every other. It is a wonderful ideal; the ingenuity which man has shown in devising means of realizing the interest is even more marvellous. But these ways of thinking are no more rivals of or substitutes for objects as directly perceived and enjoyed than the power-loom, which is a more effective instrument for weaving cloth than was the old hand-loom, is a substitute and rival for cloth. The man who is disappointed and tragic because he cannot wear a loom is in reality no more ridiculous than are the persons who feel troubled because the objects of scientific conception of natural things have not the same uses and values as the things of direct experience.

The disconcerting aspect of the situation resides in the difficulty with which mankind throws off beliefs that have become habitual. The test of ideas, of thinking generally, is found in the consequences of the acts to which the ideas lead, that is, in the new arrangements of things which are brought into existence. Such is the unequivocal evidence as to the worth of ideas which is derived from observing their position and rôle in experimental knowing. But tradition makes the tests of ideas to be their agreement with some *antecedent* state of things. This change of outlook and standard from what precedes to what comes after, from the retrospective to the prospective, from antecedents to consequences, is extremely hard to accomplish. Hence when the physical sciences describe objects and the world as being such and such, it is thought that the description is of reality as it exists in itself. Since all value-traits are lacking in objects as science presents them to us, it is assumed that *Reality* has not such characteristics.

In the previous chapter, we saw that experimental method, in reducing objects to data, divests experienced things of their qualities, but that this removal, judged from the standpoint of the whole operation of which it is one part, is a condition of the control which enables us to endow the objects of experience with other qualities which we want them to have. In like fashion, thought, our conceptions and ideas, are designations of operations to be performed or already performed. Consequently their value is determined by the outcome of these operations. They are sound if the operations they direct give us the results which are required. The authority of thought depends upon what it leads us to through directing the performance of operations. The business of thought is not to conform to or reproduce the characters already possessed by objects but to judge them as potentialities of what they become through an indicated operation. This principle holds from the simplest case to the most elaborate. To judge that this object is sweet, that is, to refer the idea or meaning "sweet" to it without actually experiencing sweetness, is to predict that when it is tasted—that is, subjected to a specified operation—a certain consequence will ensue. Similarly, to think of the world in terms of mathematical formulae of space, time and motion is not to have a picture of the independent and fixed essence of the universe. It is to describe experienceable objects as material upon which certain operations are performed.

The bearing of this conclusion upon the relation of knowledge and action speaks for itself. Knowledge which is merely a reduplication in ideas of what exists already in the world may afford us the satisfaction of a photograph, but that is all. To form ideas whose worth is to be judged by what exists independently of them is not a function that (even if the test could be applied, which seems impossible) goes on within nature or makes any difference there. Ideas that are plans of operations to be performed are integral factors in actions which change the face of the world. Idealistic philosophies have not been wrong in attaching vast importance and power to ideas. But in isolating their function and their test from action, they failed to grasp the point and place where ideas have a constructive office. A genuine idealism and one compatible with science will emerge as soon as philosophy accepts the teaching of science that ideas are statements not of what is or has been but of acts to be performed. For then mankind will learn that, intellectually (that is, save for the aesthetic enjoyment they afford, which is of course a true value), ideas are worthless except as they pass into actions which rearrange and reconstruct in some way, be it little or large, the world in which we live. To magnify thought and ideas for their own sake apart from what they do (except, once more, aesthetically) is to refuse to learn the lesson of the most authentic kind of knowledge—the experimental—and it is to reject the idealism which involves responsibility. To praise thinking above action because there is so much ill-considered action in the world is to help maintain the kind of a world in which action occurs for narrow and transient purposes. To seek after ideas and to cling to them as means of conducting operations, as factors in practical arts, is to participate in creating a world in which the springs of thinking will be clear and ever-flowing. We recur to our general issue. When we take the instance of scientific experience in its own field, we find that experience when it is experimental does not signify the absence of large and far-reaching ideas and purposes. It is dependent upon them at every point. But it generates them within its own procedures and tests them by its own operations. In so far, we have the earnest of a possibility of human experience, in all its phases, in which ideas and meanings will be prized and will be continuously generated and used. But they will be integral with the course of experience itself, not imported from the external source of a reality beyond.