THE PRINCIPLES OF SCIENCE

A COLLEGE TEXT-BOOK

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PREFACE

This little book is an attempt to bridge the chasm, which—at least for undergraduates—too often lies between scientific and philosophical studies. Its aim is to show how the inquiries of physical science lead inevitably to questions and problems which transcend the field of present-day science, that is, to questions of philosophy. Beginning as it does with a critical study of the fundamental intellectual methods of science, it may on the one side be regarded as a continuation of the student's study of logic; while, as the metaphysical questions become more numerous and prominent, it may on the other be considered an introduction to philosophy. The effort has been to start with what the undergraduate may properly be expected to be familiar with, and to carry the inquiry forward along the line of the natural development of the subject-matter—the principles of science—to those fundamental problems of metaphysics and epistemology which are either the complement or the foundation of all scientific knowledge. It is not maintained that this approach to philosophy is the best for all classes of readers; but the author believes it to be the one most natural and most useful for the average college student.

My indebtedness to Jevons' large and admirable work on this subject will be evident from the text and footnotes. I have also received valuable suggestions from my colleagues in Columbia University, Professors Dewey, Woodbridge, and Jones, and Mr. H. G. Hartmann.

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PART I

METHODS

CHAPTER I

CHARACTER OF SCIENTIFIC KNOWLEDGE—MOTIVES

How Science is Distinguished from other Knowledge.—It is a common impression that science is knowledge of things of which ordinary persons are ignorant. There is, of course, some ground for this impression, for most men are only bewildered by talk of foot-pounds and amperes, chromosomes and neurones; but science need not be, and at the outset rarely is, occupied with what lies beyond ordinary experience and thought. It is a matter of common and, indeed, immemorial knowledge, for example, that water at rest presents what seems to be a level surface; and ever since the time of Hero of Alexandria[1] in the first century, if not before, it has been a familiar fact that a tube provided with a piston and suitable valves (a pump) will draw water to a considerable distance above its former level. Yet it was with just such every-day facts as these that the science of hydraulics began. The plain man and the physicist alike know that water will rise in a pump. Usually it is only at a more or less advanced stage

[1] Hero (or Heron) was an eminent Greek mathematician who lived in Alexandria about 100 B. C. He was noted also for his writings on physics, one of which mentions a steam driven machine.

that inquiry comes upon phenomena that are quite unknown to men in general.

The first remark then to be made as to the differentia of scientific knowledge is that *it is not distinguished by its subject-matter*. Science as such is not any particular body of information, such as physics, nor even any group of these, as the physical sciences. It is not necessarily concerned with waters and metals, stars and living bodies; that is, with nature in the narrow sense. It may deal with equal propriety with the phenomena of mind, and then we have the science of psychology; and it may deal with pure abstractions, or aspects of things, and then we have the various mathematical sciences and the science of logic. Science differs from other knowledge, not in what it treats *of*, but in the *way* it treats its subjects, that is, in its *methods* [2] and as a consequence, in (1) the precision, (2) the superior certainty, (3) the universality, and (4) the organized character of its intellectual results.

(1) Scientific knowledge is *precise*, or *definite*, knowledge. It is acquainted, at least in a measure, with the conditions, the bounds, and the quantities of its object. It is aware, not only that water will rise in a pump, but that it will rise thirty-four feet, and no more. For it the statement that the piston sucks the water is not sufficient; it knows that the suction takes place because the piston exhausts the air from the pipe, leaving the water in its submerged foot without pressure from above, while the remainder of the water round about the pipe is weighed

[2] The methods of science will be considered in Chapters II–V.

down by a column of air as high as the sky. Science, it will be seen, is *exact* knowledge, whereas ordinary knowledge, including much of what is called "common sense," is inaccurate and vague in its outlines even when sound at the center.

It should be noted, however, that strictly speaking, the precision of science obtains only in regard to the ideal cases with which pure science concerns itself. Its laws are framed to state exactly how certain objects will act when free from interference by outside agencies. As a matter of practical experience, however, no case of entire freedom from interference can be found. Science says that water will rise in a pump thirty-four feet, and no more; but probably no actual suction pump will raise it over three-quarters of that height. In geometry it is a familiar fact that the demonstrations never hold entirely good when applied to physical objects, because no physical objects ever conform precisely to the descriptions on which the theorems and problems are based. We can conceive, for example, of a perfect isosceles triangle, but can never find such a thing in nature, nor yet among the constructions of men; hence all the geometric conclusions regarding such triangles are, and must remain, ideal, or theoretical. They state what would be true in the case of a perfect isosceles triangle, and what will be found to be true in other isosceles triangles *in so far as they approach the perfect type.* Substantially the same thing is true in *physical* science: The orbit of a planet is declared by the astronomer to be an ellipse, yet the movements of no planet conform precisely to this figure, for the reason that solar gravitation and its own forward movement, though they are the major forces acting upon it, are never the only ones. Gravitation toward other planets, varying in amount as these are near or far, also enters into the situation, so that no statement based solely on the mutual relations of a planet and the sun ever tells the whole truth. It may be urged that it never quite tells the truth at all, but is always more or less inexact. This criticism would be sound, if it were the aim of science to describe actual situations in nature in their detail and complexity, but such is not the case. The aim of science is the universal, the thing which is true in all like cases and despite differences of detail. To find these universals (general facts or truths) it is obliged to abstract from—that is, leave out of consideration—much that is always present in actual cases; and *it makes its statements with these variable details thus left out of consideration.* That is, its statements (laws, etc.) refer to essentially abstract or *ideal* cases, and they hold good in *actual* cases *just in so far* as the agents referred to in the statements have the field to themselves. Hence, scientific laws can be, and are, precise. *Interfering agencies aside*, the orbit of a planet is always an ellipse, and the precise eccentricity of any given planet's orbit can always be ascertained.

So of the pump: the general truth which science is concerned with—the height of the water column which the air pressure will support, say at the sea level, water and air being at certain known temperatures and the air of a given humidity—is a perfectly definite one, and may be stated with precision; but the degree to which a given pump will exemplify this truth depends upon its success in producing a vacuum in the pipe, and that, of course, will vary with the skill of the pump's maker and the excellence of his materials. It will be seen that science is exact knowledge only within its chosen field, the field of the so-called universal, or things that are true on a wide scale.

(2) Usually scientific knowledge is also characterized by *greater certainty* than that of common life. It was originally thought that there was no limit to the height to which a pump would lift water—a view which we now know to be quite erroneous. It was once a part of universal knowledge, and doubtless is so still with the majority of mankind, that the sun moves around the earth; but for educated men astronomy has disproved that conception, and, in spite of the seeming testimony of our senses to the contrary, has convinced us that the earth moves around the sun. The reasons which it gives for this (Copernican) view are so cogent that we feel certain as to the facts in a way that was impossible under the older views.

Yet certainty is not confined to science. Indeed, a scientific fact is not necessarily more certain than other facts, though it usually is so. On February 15, 1898, the U. S. battleship, *Maine*, was blown up in the harbor of Havana. This event is undubitable; yet it is not a scientific fact. It is a historical fact. It is not scientific, because it cannot be proved experimentally, or, to put the distinction in another way, it cannot be repeated. It is true that another battleship might be moored to the same buoy and destroyed in a similar way; but this would not prove that the *Maine* was blown up on February 15, 1898, but only that warships can be destroyed by explosives suitably placed. The latter would indeed be a scientific fact, but it would tell us nothing as to the fate of the *Maine*. Indeed, so far as science as such knows, the *Maine* and her crew may still be sailing the seas.

(3) From what has been said in the two sections above it is evident that a further and more fundamental distinction of a scientific fact is that it is *universal*,[3] that is, general in its application. It is an event or phenomenon which appears in an indefinite number of similar situations, and under similar conditions it can always be repeated. A historical fact, on the contrary, cannot be repeated, because the *time* and *place* of its occurrence are essential parts of the history. Thus, it is a scientific fact that the Bahama Islands lie between parallels 20 and 27, north latitude; for any competent geographer can reproduce this result for himself by computing from natural phenomena which either remain constant or are repeated at regular intervals. The historical fact, however, that one of these islands was the first land in the western world to be discovered by Columbus is a fact that in the nature of the case could happen but once. We shall have to return later to

[3] Cf. Aristotle's remark, "No art treats of particular cases; for particulars are infinite, and cannot be known." Quoted by Jevons, "Prins. of Science," p. 595.

this important distinction that science is general, rather than particular, or unique, knowledge.

(4) Finally, science is not miscellaneous knowledge, but *organized* knowledge. The rising of water in a pump has not become a completely scientific fact until it has been connected in thought with others facts, some of which precede it while others may coexist with it. On the side of the antecedent facts, or causes, the science of hydraulics recognizes that there are certain necessary conditions: A vacuum, for example, must be created in the tube; there must be no access to it on the part of the outer air otherwise than through the body of water which covers the open end of the tube; and this water must be exposed to the pressure of the outer air. Thus, in a measure the phenomenon of the rising of the water is explained by being connected as a consequent (that is, causally) with other phenomena more or less familiar. This explanation is then carried further by connecting the phenomenon with such more or less similar but not antecedent ones as the working of a lever of the first kind, and even the action of a pulley. So in both directions—as to causal interdependence and as to pertinent similarities—a scientific knowledge of the suction process is an *organized* result; it consists in interlocking that process with other known phenomena, and recognizing how it is interrelated with the general system of nature. This dual relational movement is characteristic of scientific thought. It seeks always to organize its material, to arrange phenomena in such a way as to reveal their causal articulation and their

more important resemblances. Scientific knowledge is a fabric woven by thought, of which relations of causation constitute the warp and relations of similarity the woof.

Science and Philosophy.—As just intimated, and as the student of logic is aware, *scientific explanation* consists in establishing relations—of sequence, similarity, inclusion, etc.—between the object under inquiry and some fact or law which is more familiar. It is a common notion that explanation is the answering of all questions to which a phenomenon can give rise, so that it is made entirely plain, or completely rational, to the mind; but this is far from being the case. Many questions of interest always remain. For most purposes it is no doubt a very satisfactory explanation that the 34 foot column of water in the pump is held in position by the counterpoise of a 50 (or more) mile column of air; but why do air and water have weight at all; that is, why do they press so persistently towards the center of the earth? How is it that the water in the cistern transmits the air pressure so freely to the water in the tube, which is not in contact with the air? In other words, what is the secret of the mobility of the fluid molecules? The molecules of alumina in the bricks and of iron or glass in the tube do not act in this fluent, all but frictionless way. And why are the molecules of water, with all their fluidity, on terms of seeming amity, while those of the air are on terms of aversion and in continual conflict? Indeed, how is it that a molecule or an atom ever does anything at all, either in the way of a change of place or of union with another infinitesimal individual, an individual full often quite unlike itself? These, and others that might be mentioned, are questions of interest springing out of this one phenomenon of the pump to which there is as yet no trustworthy answer, and concerning which we can only speculate. Indeed, the world is full of mysterious phenomena, partial disclosures and vague suggestions, which challenge our inquiry, but as to which though we may form, we cannot verify, our hypotheses. They are found along all the borderland of the sciences. What shall we do with them? Most men, of course, ignore them. Few inquirers in the fields where they present themselves, however, are willing to do that. They seem to be doors which science may one day unlock; [4] yet no explanations of them at present can be called scientific, because no explanations can be proved. *The hypotheses* to which they give rise *are properly philosophical doctrines*, such of these as are concerned with ultimate explanations in physics being best termed metaphysics; and the challenging but elusive facts themselves are most usefully to be described as the subject-matter, or field, of philosophy.

This view is not the only one, however, nor indeed the usual one. It is more common to claim for philosophy standing as a science, to call it, in fact, the science of sciences. Such a claim disregards philosophy's lack of power to verify its conclusions, and holds that it differs from other sciences only in having

[4] Cf. the remark of Prof. J. J. Thompson: "The progress of electrical science has been greatly promoted by speculations as to the nature of electricity."—"Elec. and Matter," p. 1.

as its subject-matter, not the phenomena of any one field of inquiry, but those which are common to all fields, or at least involve more fields than one. Thus energy as momentum belongs to the science of physics; as combining activity it belongs to the science of chemistry; as psychic force to the sciences of biology and psychology; while energy in general, its nature and significance, belongs to the science of philosophy.[5]

The former conception is the one adopted in this book, the author believing that it will conduce most to a clear presentation and a ready grasp of the principles of science. According to it *the field of philosophy is* regarded as *the penumbra*, not the strongly lighted part, *of the domain of inquiry;* and philosophic thought itself as the adventurous, speculating activity of the mind, the scout of science ranging the borderland of knowledge. This does not mean that philosophy is unscientific. Rather does it mean the contrary, that sound philosophy has the same ends and standards,[6] and in large degree the same methods, as science. Yet it does mean that, since experi-

[5] Cf. Paulsen, "Introd. to Philosophy," p. 19 f.

[6] It is the proper scandal of philosophy that so many of its representatives have written as though the canons and logical tests of science were not for them, but they were free, by virtue of the mystery shrouding their subject-matter, to reach whatever conclusions pleased their fancy. The natural consequence has been, of course, that whenever their conclusions did not please the fancy of their readers, these conclusions were rejected even more lightly than they were produced. A philosophy that is worthy of the name is scientific in spirit, and, so far as the subject-matter allows, scientific also in method, while scientific results are the ideals which it holds before itself.

mental verification is not open to philosophy, it cannot go so far as science in the way of knowledge; it cannot attain to certainty. As a consequence, serious differences of philosophic opinion are not only possible but, in view of the differences in human minds, inevitable. This is the reason why the domain of philosophy bristles with the crags of disputed questions as that of science does not. In the latter verification soon clears the field of all conclusions but one. The cases in which this is not so are cases where the question at issue is still in the philosophic borderland, and not really within the domain of science proper. The distinction, though clear, is, of course, not a fence. Philosophers continually go to science for their material, as they should; and scientists continually pass beyond experimental facts and necessary implications to speculations and theories, as is their privilege.

Motives of Scientific Inquiry.—We have seen that even in antiquity it was known that water could be raised by means of a suction pump. Why was it that men like Galileo [7] early in the seventeenth century were not content with this traditional fact, but sought to convert it into scientific knowledge? In a general way, it may be answered that the fact was essentially mysterious—water when free to move does not usually move upward, but downward—and mystery is full of challenge to inquiry. There

Galileo, or Galilei (1564–1642), was a famous Italian physicist, astronomer, and inventor. He invented the thermometer and the telescope, and made many important discoveries. His teachings were condemned by the pope, and the inquisition forced him to abjure the Copernican theory, of which he was an ardent advocate.

was a material difference, however, in the degree to which the mystery of the water's rise taxed observing minds. Some were easily satisfied. "Nature," ran the sufficient dictum of the scholastic teachers, "abhors a vacuum." Now, as a metaphorical description of a striking group of phenomena, this statement is true and useful;[8] but it is not an explanation—not, at least, until it is shown that nature is a sentient and emotional being, capable of acting upon such a motive as abhorrence.

Galileo and his fellows demanded a more definite, sure, and adequate explanation; and this Torricelli[9] at length secured by connecting the fact that the air has weight with the fact that the water will not rise more than thirty-four feet, and the further fact, ascertained by experiment, that mercury under like conditions rises but thirty inches. That is, water, which is 13.6 times lighter than mercury, will rise 13.6 times higher. Evidently the cause of the rise of each was some factor which was affected by their different weights. That common factor could only be the pressure of the external air upon the exposed surfaces of the two liquids. It is an interesting fact, as bearing upon the motives of the man of science,

[8] Whewell ("Hist. of the Induc. Sciences," I, p. 347) pronounced the principle of "Nature's horror of a vacuum" "a very good one, inasmuch as it brought together all these [mentioned] facts which are really of the same kind, and referred them to a common cause;" but he added that, "when urged as an ultimate principle," it was unphilosophical, "because it introduced the notion of an emotion, Horror, as an account of physical facts."

[9] Torricelli (1608–1647), another celebrated Italian physicist, was the pupil, friend, and successor of Galileo.

that Torricelli was greatly impressed by the simplicity and beauty of his discovery, and lamented that his master, Galileo, did not live to make it himself. Similar pleasurable emotions were aroused a little later when Pascal [10] succeeded in confirming Torricelli's conclusion. Pascal wrote to his brother-in-law, M. Perrier, who lived near the Puy de Dome in Auvergne, asking him to take a Torricellian tube to the top of the mountain, and ascertain the height at which the mercury stood there. "If," he added, "it happens that the height of the mercury at the top of the hill be less than at the bottom, it will follow that the weight and pressure of the air are the sole cause of this suspension, and not the horror of a vacuum: since it is very certain that there is more air to weigh on it at the bottom than at the top; while we cannot say that nature abhors a vacuum at the foot of a mountain more than on its summit."[11] The experiment was duly made, and the mercury on the mountain top found to stand three inches lower than at the base—a result which, M. Perrier said, "ravished us with admiration and astonishment."

The pleasure which these men evince over their discoveries goes far to answer the question why they responded so eagerly and earnestly to nature's mysteries; that is, why they sought to make knowledge scientific. They admired nature and her ways,

[10] Pascal, Blaise (1623–1662), was an eminent French mathematician and philosopher. He became noted at the age of 17 through his "Treatise on Conic Sections." Later in life he became a clergyman and an ardent upholder of the Jansenist cause against the Jesuits.

[11] Whewell, o. c., I, p. 348.

and found pleasure in studying them; or, to state the fact in other words, they had a *love of knowledge for its own sake*. This, which may be called the *contemplative* motive of science, is one that has characterized numberless investigators[12] of nature from Aristarchus[13] to Darwin.[14] The philosopher Spinoza [15] accounted it the highest of all possible motives and the gratification of it—the absorbed contemplation of the workings of nature, regarded as a causal mechanism—was dignified by him with the term "the intellectual love of God." From its point of view the world is a panorama, or better a drama, and the man of science is the privileged spectator who, by dint of mental toil, has earned the right of admission and admiring observation.

The contemplative is not the only motive of inquiry, however, and never has been. The earliest study of the stars, for example, was not so much to understand the order and movements of the shining spectacle for its own sake, as for the purpose of reading

[12] For example, the late John William Draper once remarked that many a night, when absorbed in original research in the laboratory, he had been surprised by the incoming of the morning light.

[13] Aristarchus was a noted Greek astronomer of the Alexandrian school who lived in the first half of the third century, B. C. He held that the earth moves around the sun in a circular course.

[14] Darwin, Charles (1809–1882) was a celebrated English naturalist, and one of the greatest of scientific investigators. He is noted especially as the chief author of the theory of natural selection, now so generally accepted.

[15] Spinoza, Baruch or Benedict (1632–1677), was a great philosopher who is best known as the most notable modern expounder of pantheism. He was a Dutch Jew by birth, but, though his life was blameless, he was cast out from the synagogue because of his philosophical views.

the will of the gods as to the coming fortunes of men and nations. It was astrology rather than astronomy, and its motive was *practical*, not contemplative; that is, the student hoped to get some benefit from what he learned *beyond the knowledge itself*. Much the same may be said as to the first students of chemical reactions. The wizard antedated the chemist, and his motive was practical benefit in the way of cure of disease, exorcism of demons, or the control of others through secret charms.

Prior to modern times this practical motive hardly deserved to be considered scientific, for it was commonly dominated by faith in the occult—that vague, half blind, timorous belief which we call superstition—and remained largely unenlightened. Yet there was nothing that required this alliance; and, after the renaissance, under the impulse of the humanistic movement, men of genuine scientific spirit arose who sought to join the practical interest to the contemplative. Prominent among these were Francis Bacon [16] and Descartes.[17] For them nature was not simply a wonderful spectacle to be enjoyed; it was a stupendous mechanism to be mastered and used for human benefit. "Knowledge is power," was Bacon's

[16] Bacon, Francis, afterward Lord Verulam (1561–1626) was an English jurist, statesman and philosopher of great ability. Though not a man of science, he championed enthusiastically the cause of the new science of his time. In so doing, he exalted the inductive method of inquiry at the expense of the deductive.

[17] Descartes, René (1596–1650), an eminent French mathematician, physiologist, and philosopher, is often called the "father of modern philosophy." Prof. Huxley (Cf. "Method and Results," Es. 4) accounted him of like primary importance in the field of physiology.

great formula; that is, an adequate knowledge of nature would reveal to man the reins of control of natural forces and enable him to become their ruler. Descartes held it "possible to arrive at knowledge highly useful in life," and by means of scientific acquaintance with natural forces to apply them "to all the uses to which they are adapted, and thus render ourselves the lords and possessors of nature."[18]

In our own time the practical motive has abundantly vindicated itself, not only in applied but also in pure science. Investigators like Koch[19] and Pasteur[20] who devote years of labor to the discovery or invention of a serum which will control a deadly disease are not regarded as coming short in any respect in true scientific spirit. Nor does there appear to be any reason why the practical motive should not play a major part in research. Certainly it has been the practical side of science, its services to human needs, that in modern times has given it its hold upon popular confidence and banished the medieval fear of it as a kind of magic. Then, scientific inquiries are, of course, pursued for some end; and it does not appear why the promoting of human health, and the release of human energies through useful inventions and the control of natural forces from the bondage of toil for mere self sustenance,

[18] "Discourse on Method," Pt. VI.

[19] Koch, Robert (1843–), a celebrated German physician, is the discoverer of the bacilli of tuberculosis and cholera. In 1905 he received the Nobel prize in medicine.

[20] Pasteur, Louis (1822–1895), a great French chemist and microscopist, is famous especially for his researches in bacteria, fermentation, and hydrophobia.

are not as worthy ends for scientific endeavor as the disclosure to intellectual contemplation of nature's agencies and mechanisms.

No doubt it may go astray. It may take on a sordid character, a greed for commercial results, that is in strong contrast with the noble disinterestedness which scientific inquirers have usually displayed. A more serious danger is that of narrowness of vision through haste for a serviceable outcome; a neglect, for example, of exceptional and residual phenomena. It is especially at this point that it needs to be supplemented by the contemplative interest. To approach nature with more of craving for her material gifts than of interest in herself is not the way to penetrate her mysteries, as in time alchemism discovered.

There is a wider sense of the word "practical" emphasis upon which is not seriously beset with the dangers just mentioned. It is the sense of *instrumental*, or serviceable to a valuable end of some kind, *including the end of acquisition of further knowledge.* Thus it was a practical, or "pragmatic," motive which led Newton [21] to labor so patiently to determine the precise departure of the moon's orbit from a tangential course. The satisfaction in view in that case was not primarily the intellectual pleasure of knowing the precise curve itself, but that of testing his hypothesis of universal gravitation. The result

[21] Newton, Sir Isaac (1642–1727), was an eminent English mathematician and physicist. He is most famous for his formulation of the law of gravitation; but he was also a distinguished investigator in physics, notably in optics.

when achieved would serve a valuable end of knowledge beyond itself. Indeed, the moment we take the word practical in this way, we see that the bulk of the patient toil so characteristic of modern science is undergone through practical motives. Only the larger discoveries, if any, are interesting enough to reward the investigator through their own inherent, or esthetic, value; most new facts are prized because of the larger results to which they may lead.

It should be noted also that even the path of the contemplative interest is not free from pitfalls. Under its sole control the investigator is *prone to be swayed by private liking*. He who inquires into nature purely for the pleasure of becoming acquainted with her more intimate forms is especially likely to interpret what he sees in ways pleasing to himself. It is along the line of this tendency that philosophy and theology have so often led science into the ditch. Thus, Aristotle accounted for the fact that a weight on the long arm of a lever will move a greater one on the short arm by saying that the former moved in a larger circle, and that the circle was essentially wonderful, because it combined the opposites of a stationary point and a moving line. The line, too, was both convex and concave.[22] From analogous esthetic reasons the church denied the existence of more planets than five. These with the sun and moon made seven, which was a perfect number; and what but perfection was to be expected in the heavens? [23]

Furthermore, the contemplative motive seems

[22] Quoted by Whewell, o. c., I, p. 84 f.

[23] Cf. Jevons, "Principles of Science," p. 623 ff.

generally to have induced a philosophic attitude which is open to serious question—the disposition to assume the fundamental, or underlying, changelessness of the world. The thought of witnessing a spectacle is apt to suggest, though it does not necessitate, the idea that somewhere back of the shifting scenes there is an agent or machine or framework which remains always the same, maintaining the spectacle by doing the same thing over and over. Indeed, in one of the earliest and most influential of the Greek schools of thought—the Eleatic—the very existence of change was denied, and the seemingly endless mutation of nature was declared to be illusion.

In these respects the contemplative interest has found a valuable corrective in the practical. The concern of the latter being with what will render service, either material or intellectual, it is freed on the one hand from the tendency to favor certain pleasing types of explanation, while on the other it is under continual incitement to put its theoretical constructions to the test of experiment. Its motto naturally is, whatever will work, and work best, is to be approved. Both motives are needed for sound scientific advance, though in individual investigators one may properly enough predominate over the other according to natural bent of mind.

Exercises

1. Point out the four characteristic marks of scientific as distinguished from ordinary knowledge in the cases of ——

   A. The nature of the sun and its relation to the earth;

   B. The nature of light and the process of vision.

2. Give three instances of collision between ordinary ideas and truth as scientifically established, showing in each case why the scientific account of the matter should be accepted.

3. When Cavendish (about 1784) discovered that water could be decomposed, and the resulting hydrogen burned in the air with water as the result, show why the discovery itself was a historical fact while the composite nature of the water was a scientific fact.

4. A. Show when psychology and sociology may be considered to be genuine sciences, and when they are to be regarded as branches of philosophy.

B. What change or further development in ethics and theology would be necessary before they also could be recognized as sciences in the strict sense?

5. A. Make a careful abstract of J. A. Thomson's "Introduction to Science," chapter I.

B. Do the same with his fifth chapter.

6. In the following extracts and cited passages tell which scientific motive predominates in each, and give reasons for your opinion. If both motives are present, show how they reveal themselves.

(1) "Believe it, my good friend, to love truth for truth's sake is the principal part of human perfection in this world, and the seed plot of all other virtues."—John Locke.

(2) "If God should hold absolute truth in his right hand, and everlasting search for truth in the other (though without hope of ever reaching it), and should say to me, 'Choose!' gladly would I kneel down before him, and say, 'Heavenly Father, give the everlasting search.' Truth will make me lazy, vain, and unproductive; search for truth alone can make me happy."—Lessing.

(3) Locke's "Essay concerning Human Understanding," prefatory "Epistle to the Reader."

(4) Young's "General Astronomy," introduction.

(5) Darwin, "Origin of Species," Conclusion.

(6) Huxley, "Introduction to the Study of Zoology", pp. 1-3.

(7) Kropotkin, "Modern Science and Anarchism," conclusion.

7. Make an abstract of Karl Pearson's "Grammar of Science", Introd. secs. 2-4, 9, and 10, and show which scientific motive he emphasizes.

8. Make a careful synopsis of Paulsen's reasons for calling philosophy "the sum-total of all scientific knowledge." ("Introd. to Philos." pp. 15-44).

CHAPTER II

PRINCIPLES—THE TWO FUNDAMENTAL METHODS

Principles of Science are Established Ideas of General Application.—If science is exact, certain, universal, and organized knowledge, what is a "*principle* of science"? The term has a somewhat loose application, standing, as it does, for three distinct kinds of ideas. It can at least be affirmed, however, at the outset that a "principle" is always an *idea*. It is a product of thought, not an object of sense perception. It is a *truth*, not a fact in the narrow sense, that is, not a phenomenon.

When Franklin [1] flew his kite in the thunder-storm, he did elicit a new phenomenon: electric sparks sprang from the charged cord. This evidently was a *fact*, a concrete matter of observation by the senses. But when he drew the general conclusion that the lightning itself is but a huge electric spark, a tremendous manifestation of static electricity, he was asserting a *truth* rather than a fact. His conclusion was reached by a process of thought, not by sense percep-

[1] Franklin, Benj. (1706–1790), a great American statesman, philosopher, and author, is best known as the able and faithful upholder of the cause of the American colonies in their revolt against Great Britain; but his vigorous mind was greatly interested also in natural inquiry.

tion alone, though of course the objects of sense—sparks, lightning flashes, etc.—were *used* by thought. Furthermore, it was *general* in its application. He affirmed, not merely that those particular sparks given off by the cord were electrical, but (by the so-called inductive leap of thought) that *all* lightning flashes are electric sparks.

(1) In reaching that general conclusion, which has held good since, Franklin established a scientific principle; for one meaning of the term, principle of science is, *Any* **result** *of scientific inquiry which is general in its application, and in the discovery of which reflective thought plays a leading part.* Such scientific principles may be called *Empirical Principles,* since they are the *results of experience worked over in the mind*; or they may be called *Material Principles,*[2] seeing that they constitute an important part of the material with which science works.

(2) Franklin's discovery, however, illustrates another kind of scientific principle, for it involved certain *methods of thought* that are distinctive of science, and these, when generally approved, are also called principles. How did it occur to him that the Leyden jar and its spark might hold the secret of the thunderstorm? The two phenomena have striking differences. The jar is small, hard, motionless (apart from the occasional spark), and still, except for the snapping sound at the moment of discharge. The storm-clouds, on the contrary, are vast, ill-defined, surging with tumultuous movement, and charged with awe-

[2] And so distinguished from the *formal* principles of logic and scientific method.

inspiring rumblings which break every now and then into astounding crashes. Why connect the two? It is evident that no one would do so who surveyed them as wholes. Only after the observer had in thought separated the jar and the storm phenomena into their component parts, that is, *analyzed* each, and had dropped out of consideration for the moment the many features in which they differ—only then would it have occurred to him that the lightning was after all but a huge electric spark. The two flashes, or sparks, are indeed much alike except as to size, but this likeness discloses itself only when they are thought of *apart from their exceedingly diverse accompaniments.* Now, the process of dividing an object into parts, either physically or mentally, in accordance with the lines of its structure, is called *analysis;* and it is a cardinal principle of science, though a *Methodological* (or formal) and not an Empirical one. So important is it that it is not too much to call it the vestibule of the temple of science.

Another methodological principle plays an equally important part in Franklin's discovery; for he evidently put some things together as well as took others apart. The spark which he drew from the kite cord did not of itself tell him that it was electrical, nor yet that it had come from the storm-cloud. It simply acted according to its nature, and that way of acting, being much like the phenomena of the Leyden jar, *Franklin's thought connected* with the familiar, that is, electrical, sparks of the latter. Moreover, as there appeared to be no other possible origin for it than the cloud out of which the lightning sprang, *his thought traced it back* to that same source. Indeed, it did more; for it conceived of the storm-cloud as containing stores of static electricity in essentially the same way as a Leyden jar contains them. This is evidently a movement of thought in the opposite direction from that of analysis. It puts things together instead of taking them apart. It is a constructive, phenomenon-joining process. It is mental, or logical, *synthesis*; and synthesis, quite as much as analysis, is a cardinal principle of science. Indeed, these two, analysis and synthesis, together with certain regulative principles for safeguarding synthetic thought processes, may be said to constitute the methodological, or formal, principles of science. Scientific method, so far as it is a matter of thought, and not of technical manipulation, is essentially a critical distinguishing, or mental separation of phenomena into their fundamental elements or factors, and then a recombination of these in thought according to pertinent relations of resemblance and sequence, as outlined in the last chapter.

(3) There is still a third kind of scientific principle involved in Franklin's thunder-storm experiment. He *assumed* something in drawing his conclusion; indeed, he assumed it in flying his kite at all, and *he had to assume it.* The assumption was that what he found to be true that day would be true, under like conditions, on all days. Without this general principle, commonly known as the *uniformity of nature,* his conclusion that the lightning is (on all occasions) an electric spark would have been no scientific principle at all, for it would have lacked generality of

application. Yet, as will appear in the third part of our study, this principle is not an empirical one, for it is not *proved* by experience—though it *is* confirmed —nor is it provable by experience. Neither is it a methodological principle, a way of investigating. It is something *assumed*, a belief adopted, *because we need it.* The justification of it is not any proof, but the fact that it appears to be *necessary for the existence and progress of science.* Whatever fundamental assumptions, or postulates, are thus necessary constitute *the third group of scientific principles.*

These Distinctions of Kind not Absolute.—No absolute line of demarcation can be fixed between the three kinds of principles described above—empirical, methodological, and postulated. For example, while it is a prime characteristic of empirical principles, such as Newton's law of universal gravitation, that they are *results,* or fruits, of inquiry—that is, they are *discovered*—yet in a sense methodological principles, too are discovered. They are not the property of the mind in advance of experience; rather does the groping, sentient organism stumble upon them in the course of its instinctive search for satisfactory experience. The methodological principle of analysis no doubt seems instinctive or innate to many who have been educated in modern schools; but it was not so to men originally. Its value had to be learned by use; that is, it was a discovery. It is properly simply a way in which mind has come to act successfully, at first by accident, later through the natural preference for what yields satisfactory results. On the other hand, an empirical principle, like that of gravitation, while it is a discovery, is yet of such world-wide application that it gains also a certain methodological character, because it conditions all subsequent natural inquiry. No mechanical investigator would think for a moment of leaving gravitation (weight) out of account in his hypotheses and experiments. It has become for him a guide in investigation, and a standard for expectation, and is thus in a measure methodological, although primarily empirical. Again, a postulated principle, like that of uniformity, may find confirmation so constantly in experience as to be taken by many for an empirical one—a discovered truth.

Nevertheless the distinctions made are of value. A fundamental postulate does differ from a methodological principle in stating something about nature *as true*, and from an empirical principle in requiring acceptance *without proof*, that is, on fundamentally *practical* grounds. Empirical and methodological principles also do differ from one another in the important respect that the former present us with *actual experience in its relations* while the latter are simply ways of ascertaining those relations; the former are the *results* of scientific method, while the latter *constitute* scientific method. Furthermore, while methodological principles are in a sense discovered, they were not originally, and are not generally, discoveries due to effort directed to any such end. In the main, they have been found by accident. Like Saul searching for his father's asses and finding a kingdom, they are the rich incidents of inquiries which had a different purpose. Methodological, also, differ from empirical principles in that in themselves they tell us nothing about the natures of things. The principle of analysis, though no doubt it suggests that things are more or less susceptible of separation into parts, yet *in itself* tells us nothing about the constitution of the world. It is merely a *way* of going to work.

In the discussion of these three types, the basic conceptions, or fundamental postulates, will be considered last, that being their actual position in critical recognition. Of the other two, the empirical principles, being the results of inquiry, are those which bulk largest in the popular eye. The critical student, however, recognizes that the *processes* of science—its *methods*—being the means through which the results have been achieved, are equally worthy of study; and, since they are organically connected with the processes of logic—supposed to be familiar to the reader—these will occupy us first.

Methodological Principles—Analysis.—It was unquestionably long before the dawn of either science or history that men discovered that they could understand things better by considering them piecemeal—part by part. Crossing of streams, scaling of crags, and conflicts with beasts must very early have taught them this lesson. Indeed, to act upon more or less discriminating examinations of objects no doubt became a habit, and a quasi-hereditary habit, long before reflection arose and men became *aware* that they were taking things apart in their minds, that is, analyzing them. Much later still was it when it occurred to thinkers to formulate a *rule of inquiry* to the effect that the subject-matter under investigation should always be separated into the simplest parts possible. So late as the seventeenth century Descartes announces this rule of method as one of his own discovery—"to divide each of the difficulties under examination into as many parts as possible, and as might be necessary for its adequate solution."[3]

This was a sound practical insight of Descartes, for in the analytic process there is a systematic focusing of attention upon part after part which makes for clearer and more thorough perception. Less obvious elements, which might easily be overlooked, are brought into notice, and the connections between them recognized. Every one who has taken a machine apart attentively knows how much he learned about it by so doing. Analysis does more, however, than bring out the detail. As we saw in the case of Franklin's discovery regarding the lightning, it makes possible also the recognition of underlying similarities between things—for example, the common nature of the electric spark and the lightning flash. Hence it is the first stage of classification and generalization, and so of induction also, which starts with generalization. It is no less needful for the recognition of fixed sequences (causes and effects). When we look backward searching for the cause of an event, it is only by careful analysis of the preceding situa-

[3] "Method," Pt. II, 2nd Rule. If this was a new discovery to Descartes, it was not new to thought at that late day. It was substantially identical with Galileo's "Method of Resolution," which was but the broadened, empirical application of the scholastic *Methodus Resolutiva*, which in turn was derived from the teachings of Aristotle.

tion that we are able to determine the indispensable antecedents;[4] and when we look forward and seek to anticipate effects, it is impossible to do so successfully unless we study the present situation analytically, and make sure just what the circumstances are. A Leyden jar, for example, will act in a given way only when the conditions are right; and these conditions are to be known only by analytical observation.

Now, as we learned in Chapter I, the great aim of science is to establish relations of these two kinds, similarity, or common character, and fixed sequence, or cause and effect. A fact, or phenomenon, which it can relate up with no other facts, either by significant resemblance or uniform sequence, is for science far from being a satisfactory thing. It is a puzzle and a challenge, a problem to be solved; and the solution always begins with analysis, that is, critical, discriminating study. It is evident, therefore, that analysis is the fundamental or initial process in distinctively scientific inquiry.

Synthesis.—Synthesis is, of course, the antithesis of analysis, being constructive over against the quasi-destructiveness of the latter process. It consists in putting together relatively simple things in such a way as to produce complex or (better) compound results. The syntheses of the chemical laboratory by which acids, bases, and salts are produced are familiar illustrations of the process in general. Synthesis in all departments is a cardinal scientific method.

[4] The student is supposed to be familiar with this fact through his study of the inductive methods of logic.

Like analysis it leads to a better understanding of the phenomena under examination by securing closer attention to the parts and the interrelations of things and processes. To know how things go together to make a whole is something more than to know them separately, or even to know the whole and how it comes apart. A child soon learns to take a toy to pieces, but the knowledge thus gained is vague compared with that attained when he learns to put it together again; and the principle holds true in later life when the child becomes a mechanist or a chemist.

Mental Construction.—We, however, are concerned only with the type of synthesis which is common to all the sciences, and to the arts and ordinary life as well, that is, *mental* synthesis, which is also called logical construction; and in this direction the bringing out of detail is but a small part of the service that synthesis renders. Through mental synthesis made under proper conditions we are able to attain results which perception alone (observation etc.), however analytic, can never furnish. That there are chemical compounds, synthetic products of the chemical laboratory, which are never found native—many explosives, for example—and which therefore could never be discovered by analysis, is a familiar fact. Equally true and vastly more important is the fact that in the realm of thought there are many things, both existences and laws, which are discoverable only by *putting together* in critically approved ways the elements of knowledge which analytic observation furnishes.

The solar system as such is an example. As the children of modern culture we all of us accept the Copernican-Newtonian account of it. Relatively to our planet, we affirm without question that the sun is the central and fixed body and the earth the revolving one. So of Venus and Mars and the sister planets—all move in elliptical orbits regularly and ceaselessly around that one vast shining orb. How do we know this? Assuredly not by the uncriticized evidence of our senses, for to our eyes, as to the eyes of Greeks and Chaldeans, the sun *seems* to move across the sky, and the planets seem to shift their places in perplexing ways that are by no means elliptical, and that apparently did not suggest ellipses to any one before Kepler.[5] Most of us, of course, accept the modern view on the authority of the astronomers. Probably a large number of persons add to this (proper) credence the notion that the astronomer with his telescope is able to see these heavenly movements as they really are. Such is far from being the case. So far as the apparent movements of sun, moon, and stars go, the telescope tells precisely the same story as the naked eye. The astronomer in interpreting the planetary movements has to do the same thing as the rest of us, that is, set aside the ordinary, and seemingly instinctive, inferences of the mind concerning what it perceives, and has to imagine for himself a system of movements which are largely different from what he witnesses through

[5] Kepler, Johann (1571–1630), an eminent German astronomer, was one of the founders of modern astronomy. He discovered that the planets move in ellipses, not circles, with the sun at one focus; and he framed in mathematical terms the great laws which describe their movements.

the telescope. As little as any other man has he ever *seen* the earth, or any other planet, move around the sun. He conceives the planets so to move, because such a conception, when *all* the perceived movements are taken into account, explains them better. His modern conception is more satisfactory by far than the ancient views in the way of providing the solar system with an (inferred) mechanical and dynamic machinery which is at once simple and in harmony with known mechanical laws. Therefore he adopts that conception, and tells us it is true. No man, however, has ever seen the solar system *as a system*; that is as a vast cluster of bodies in unitary elliptical movement. *It is a construction of the mind*; it is *manufactured* knowledge.

Other examples of such systematic synthetic thought are the geologic history of the earth, the molecular constitution of material things, and indeed all laws of nature, all of which are constructions of the mind, and none of them objects of perception.[6]

Materials of Thought.—It is important to note that mental construction works with two, or more, distinct kinds of material. There are, *first*, the objects of sense perception—stones and stars, liquids and gasses, plants and animals—and, *second*, various

[6] When thought syntheses are made in the order of their complexity, we have the type of mental process which Descartes commended when he formulated his rule of conducting his thoughts in such order that, by commencing with objects the simplest and easiest to know, he "might ascend by little, and as it were step by step, to the knowledge of the more complex." ("Method," Pt. II, 3d Rule.) This corresponds largely to Galileo's "Method of Composition" and the scholastic *methodus compositiva.*

universal ideas or laws, such as chemical affinity, inertia, and the other empirical principles of science. The first are concrete existences which prove themselves by the way they affect us; they are the *data*, the *facts* or phenomena of science. The second are abstract, theoretical factors, which are properly to be received as actual existences only in so far as they are found to be *involvea in* the facts. At their best they are truths or principles; often they are mere hypotheses. In addition to these two elements in mental synthesis, there may be, when need arises, a *third* or intermediate kind of material, that is, concrete objects which, being purely theoretical, have the rank of concrete ideas and not of facts. Such are molecules and atoms, the ether and the soul.

In the mental construct which we call the solar system the moving, shining dots in the sky, together with the sun and earth, constitute the facts or *data;* the notions of motion, momentum, gravitation, etc., are the universal ideas; while the ether, which is posited (that is, affirmed to exist) for the purpose of explaining the solar system's optical phenomena, belongs to the third group of the mind's construction materials—the *concrete* ideas.

The thought that the mind in its syntheses uses *materials* naturally raises the question, how these materials are supplied. So far as the first kind is concerned, the answer is evident: they are supplied by sense perception—sight, touch, hearing, etc.—though in scientific thought the effort is always to have the perception, that is, observation, of an analytic and critical character. The theoretical factors in mental construction are not given sc immediately. They are abstract; that is, they have been *drawn* by reflective thought *from* the facts, usually through a comparison of a large number of objects. They are thus mind-made, and by processes of which analysis is the first and all-important step. In general, therefore, we may say that observation and analysis furnish the materials by means of which synthetic thought rears its edifices of knowledge. The synthetic thought itself seems to consist largely in selecting judiciously from these materials and putting together the elements (facts) so chosen in one way after another until a combination of them is found which forms a scheme of the way things exist and act in the world which is satisfactory to the mind.

Synthesis, Analysis, Cause.—The philosopher Spinoza would not allow that any acquaintance with an object was properly to be considered knowledge which did not include acquaintance with its cause. Scientific thought is of much the same opinion. For the man of science causal knowledge is the highest kind of knowledge. But *knowledge* of things through their causes is itself evidently a synthetic process; it involves a putting together in the mind of perceptions (the phenomena present to the senses) and other objects remembered or conceived (the causes). It is allied to deduction, which is also synthetic, the premises being combined to produce the conclusion. On the other hand, the *discovery* of causes requires analysis, as is evident when we reflect on how Franklin discovered the cause of the lightning to be electricity. In dealing with phenomena, we approach natural processes from the effect end, an end which is the concreted result of many causes efficient in varying degrees, and to find these causes—now no longer on the scene—patient, critical analysis of the traces left by them in the effect is necessary. Such analysis, supplemented as it must be by clear insight and wise synthesis, is generally a difficult and slow process, as anyone may see who will compare the difference in ease in constructing and guessing a riddle. Natural situations generally present themselves to the inquirer as riddles, and riddles to which commonly his clues seem all too scanty.

Jevons has laid a just emphasis upon this truth in his distinction between the *Method of Discovery* and the *Method of Instruction.*

"The method of discovery," he says, "is employed in the *acquisition* of knowledge, and really consists in those processes of inference and induction by which general truths are ascertained from the collection and examination of particular facts. . . . The second method (Instruction) only applies when knowledge has already been acquired and expressed in the form of general laws, rules, principles, or truths, so that we have only to make ourselves acquainted with these and observe the due mode of applying them to particular cases, in order to possess a complete acquaintance with the subject" [7]—as, for instance, in mastering a foreign language or a natural science *from a text-book.* "The principles of mechanics . . . seem comparatively simple and obvious as explained to us in books of instruction. But the early philosophers

[7] "Lessons in Logic," p. 202.

did not possess such books; they had only the Book of Nature in which is set forth, not the laws, but the results of the laws, and it was only after the most patient and skilful investigation, and after hundreds of mistakes, that those laws were ascertained" [8], so much slower is the method of discovery. "A few nights of observation might have convinced an astronomer, viewing the solar system from its center, that the planets traveled round the sun; but the fact that our place of observation is one of the traveling planets so complicates the apparent motions of the other bodies, that it required all the sagacity of Copernicus to prove the real simplicity of the planetary system. It is the same throughout nature; the laws may be simple, but their combined effects are not simple, and we have no clue to guide us through their intricacies. 'It is the glory of God,' said Solomon, 'to conceal a thing, but the glory of a king to search it out.' The laws of nature are the invaluable secrets which God has hidden, and it is the kingly prerogative of the philosopher to search them out by industry and sagacity." [9]

The distinction between these methods is a just and important one; yet it is to be doubted if it corresponds as closely to the difference between analysis and synthesis as Jevons thinks. The searching out is by no means a matter of *mere* analysis. Indeed, his concluding word "sagacity" suggests the contrary. The synthetic processes of association, selection, hypothesis, and verification are also required. Nor,

[8] Id., p. 204.

[9] "Principles of Science," p. 126.

on the other hand, is the logical exposition of a subject ever a matter of *pure* synthesis. The expositor must arrange the parts of his subject in a logical way, and this requires him to analyze it afresh. The truth is that analytic and synthetic thought processes are complementary, like the opposite swings of a pendulum. Thought would soon come to a standstill if confined to either alone.

Exercises

1. It is now established that the dark transverse lines in the solar spectrum discovered by Fraunhofer, and named after him, are identical in position with the bright lines which constitute the spectra of certain substances, and that the dark lines are due to the presence of the vapors of these substances in the atmosphere of the sun, since a luminous body (such as an incandescent gas) absorbs at a lower temperature the very type of ether waves which at a higher temperature it emits. (Cf. Kimball's "College Physics," pp. 620-629). Show in some detail how each of the three main kinds of principles of science are involved in this discovery.

2. A. Point out all the cases of analysis which occur in any two of the following passages:—

(1) Tyndall, "Forms of Water," secs. 1 and 2.
(2) Darwin, "Descent of Man", I, pp. 5-11.
(3) Lodge, "Modern Views of Electricity", chap. I.
(4) Young, "The Sun," introd.
(5) Shaler, "Aspects of the Earth", pp. 1-14.

B. Do the same with all the cases of synthesis that occur in these passages.

3. A. When we say we know the earth to be a sphere, what parts of that knowledge are actual perceptions (knowledge through the senses), or facts, and what parts are due to mental synthesis?

B. Make the same distinction in the case of our knowledge of the hydrogen atom as the lightest of the atoms.

4. Make plain the three different kinds of thought materials (telling which is which) involved in the scientific account of combustion as being a process of combination of oxygen atoms with atoms of carbon and hydrogen, the outcome being the compound molecules CO_2 and H_2O.

5. Why is discovery so much harder than instruction? Illustrate the matter.

(1) From the case of Columbus and the egg.

(2) From that of repeating, or even making, a riddle and solving it.

(3) From that of the circulation of the blood as it appeared to Descartes ("Method" Pt. V) and as it appears to the student of a modern text-book on physiology.

(4) From that of the nature of Induction, as explained by Jevons in his "Principles of Science", pp. 121-126, 127-8.

6. Make a careful abstract of chapter 3 of J. A. Thomson's "Introduction to Science."

CHAPTER III

POSITIVISM

Dangers of Mental Construction.—It must have occurred to some readers of the last chapter that mental synthesis is a process very liable to error. Human constructions of all kinds are faulty at first, the faults often entailing disaster; and it is not otherwise with the constructions of thought. Rather do man's mistakes in forming complex ideas (explanations, plans, etc.) seem to be the main causes of his failures in new practical enterprises.

Perhaps no more pitiful story has come down to us than that of the children's crusade, a romantic undertaking through which in the twelfth century some fifty thousand children either perished at sea, or elsewhere, or were sold into Moslem slavery.

The movement was the outcome of a process of constructive thought, partly religious and partly metaphysical. Starting from Bernard of Clairvaux's [1] not unreasonable claim that the failure of the second crusade was due to the sinfulness of the crusaders, it was argued that a crusade conducted by innocent and zealous individuals—children, for example—could not

[1] Bernard of Clairvaux, Saint (1091–1153), was a French ecclesiastic of the highest character, and of great popular and political influence. He was a Cistercian monk, who in time became abbot of the monastery of Clairvaux. He preached the second crusade.

fail to succeed. Was not the crusading cause the cause of God, and could he possibly allow it to fail when those embarked in it—the innocent children—were true and worthy representatives of it and him? It is easy to look back upon this argument now, and see that it was a nest of assumptions; but it was not easy to see the error of it in Western Europe in the twelfth century; for the righteousness of the Christian cause in the conflict with Islam was the conviction of virtually every one, while the line of action expected of the Deity was precisely that which would be taken by a high-minded feudal ruler. The children's crusade was thus a case where plausible, but none the less erroneous, mental construction led to disaster. Unhappily it was but a specially pitiful example of an innumerable class.[2]

Another and recent instance on a large scale is the collapse on August 29, 1907, of the great Quebec railroad bridge, then in process of construction. Without warning it fell of its own weight into the waters of the St. Lawrence, carrying seventy-four workmen down to death and reducing 20,000 tons of steel to scrap. To the bridge engineers of this country this was a catastrophe of the first magnitude; for the destruction of these men and the loss of millions of money were due neither to the rage of the elements nor to any imperfections in the foundations,

[2] It should not be overlooked that an edifice of thought may do harm when no manifest mischance is reckoned to its account; for it may stand when it should fall. It may remain as an obstacle in the path of progress generation after generation, as did, for example, the long established doctrine of man's central position in the universe.

but purely to miscalculation on the part of the engineers. They were attempting a mechanical construction on an unprecedented scale—virtually doing a new thing—and their plans failed to work.

There may be conservatives who will argue from such facts that men should refrain from mental constructions, or at least from acting upon them; but the more active part of mankind will not heed such counsels, for it is through mental constructions tested in action that progress in civilization is made. Yet it is evident that synthetic thought, though it is indeed a process of highest importance, is yet fraught with grave danger, and that controlling principles or rules for safeguarding it are greatly needed. In the course of scientific discussion in the last five hundred years several such principles of thought control have been proposed, and some of them have won their way to general acceptance. In the main, they are principles of what is known as *rigor* or severe caution. Their aim is to restrain the mind's combining activity, and keep it to safe courses; to put a bit into the mouth of the psychic Pegasus and keep him from throwing his rider.

When one reflects over the argument in justification of the children's crusade, the most remarkable thing about it from our modern point of view seems to be the small account it takes of every-day facts. Innocence and religious zeal are *assumed* to be evidence of heavenly appointment; there appears to have been no inquiry as to whether these qualities were *actually* divine credentials for a religious war. Moreover, children in ordinary life, whatever their innocence and zeal, are not more immune than adults from disease, from drowning when shipwrecked, and from the violence of ruthless soldiery; neither do such qualities render them proficient and powerful warriors. Yet just these unchildlike characteristics the argument required them to display when they were enrolled as crusaders. That expectation was evidently based, not on facts, but on theological theory, as was so common in the middle ages.

Positivism.—In reaction from this kind of thinking, and in opposition to it, the first principle of rigor to make its way to general acceptance, and thereby to mark the commencement of the modern era, was what is now known as *scientific positivism.* Toward the close of the middle ages the conviction arose that a primary place in thought constructions should be given to *facts* as distinguished from doctrines, that is, theories *about* facts. The conviction came to clear expression first in the English Franciscan monk, Roger Bacon,[3] who as has been said, with all his energy "called the science of his time from authorities to things, from opinions to sources, from dialectic to experience, from books to nature." [4] This teaching was continued by his successors in the Franciscan order—also Britons—Duns Scotus and William of

[3] Bacon, Roger (1214–1294), was an English Franciscan friar of original mind and great attainments. He, with the two other notable British Franciscans who succeeded him—Duns Scotus and William of Occam—may be regarded as the direct source from which modern scientific thought has sprung. He was imprisoned many years by his ecclesiastical superiors on the ground of heresy; but the heresy seems to have been merely the modern scientific principle that facts rank higher than theories.

[4] Windelband, "Hist. of Philosophy," p. 344.

Occam. It is a matter of course in the thinking of to-day; but at first it won its way but slowly against the doctrinaire habits of centuries. In the revival of physical science which followed the renaissance, however, it met with an enthusiastic response. Francis Bacon, often regarded as the originator of it, was really but the mouthpiece of the science of his day in his insistence that the facts of nature as discovered in experience are the most certain and authoritative elements of knowledge.

Positivism [5] stands for the underlying or regulative conviction of men of science that facts (that is, phenomena vouched for by the direct evidence of the senses) are present to us and exist for us in a real, lively, coercive way attained by no other object of the mind. Other things being equal, the more immediate a cognition is the higher its rightful rank in the scale of certitude. Facts, being largely immediate knowledge, constitute the data of inquiry, the fundamental building material of knowledge, its construction stones, first to be quarried (discovered) and then to be built into its walls. In the long generations of medieval discussion it had been customary to give past generalizations and interpretations authority over new discovery. According to the logical canon of agreement new truth should agree with old; it was too often overlooked that this rule applies only to new mental construction, not to new data. So, with endless hindrance to the advance of knowledge, the effort was to force every new fact

[5] Only scientific positivism is referred to here. Philosophical positivism will be considered later.

under the form—too often under the yoke—of past interpretations. When this was not feasible, new phenomena were apt to be ignored, or indifferently dismissed as exceptions.[6] The principle of positivism holds, on the contrary, that attested phenomena have a certainty and a normative value which set them in a class by themselves. To use them successfully it is necessary to take them as they are, regardless of theoretical consequences. When genuine, they are unyielding, uncompromising, insistent; while mental construction is, or should be, pliant and accommodative. The latter should never be coercive until the facts make it so; it should be subservient to phenomena, and never seek to override them or explain them away. Even laws should never become authoritative requirements *laid upon* the facts, but rather authoritative declarations issued *by* the facts. Indeed, no theory or law, however well established, is safe from attacks due to newly discovered (and attested) phenomena. The modern astronomer does not hesitate to challenge even the law of gravitation, if stellar movements appear to conflict with it.

The principle of positivism though rarely questioned is yet not so firmly established as to be beyond trespass. The theorizing, constructive tendency of the human mind is often restive under it, even in scientific adherents. For example, it is a claim frequently made in behalf of physical science

[6] The contrast of this habit with the modern scientific custom is seen in the fact that to Darwin the exceptions were the points of greatest interest.

that it assumes the world to be rational throughout, all events being governed by intelligible laws. The seeming exceptions to the reign of law, it is urged, are really but cases of the interaction of other agencies, themselves perfectly orderly, so that to an intelligence capable of understanding the cosmos as a whole there would be no exceptions, no chance, nothing without a "sufficient reason." [7] We shall have to consider this conception later.[8] It is sufficient here to observe, that, if, as is apt to be the case, the assumption is made as a binding one, and not merely as a matter of faith, it evidently violates the principle of positivism, because it demands in advance that new phenomena shall agree with past mental construction. Positivism in science is a kind of declaration of independence of all such authoritative demands, a matured determination to make theory and law interpretative and summarizing *servants* of the facts, not marshaling *dogmas* to beat them into line.

Law of Parsimony.—Mention has been made of William of Occam as a prominent medieval positivist. To him we are indebted for a classic working rule which embodies the positivist spirit, though it does not use our modern terms. He laid it down as a cardinal maxim of inquiry, that "Theoretical existences are not to be increased without necessity." [9] It will be observed that this rule puts no limit upon the increase of facts. The field of knowledge is left

[7] Leibniz' term.

[8] Cf. Chapter XII, *infra*.

[9] *Entia non sunt multiplicanda præter necessitatem.*

unrestricted, so far as they are concerned. It does, however, lay a stringent, albeit flexible, restriction upon the second and third kinds of thought materials. These are to be shut out altogether, *except* so far as they are found to be necessary for the understanding of the facts. The true intent of Occam's rule is given in Sir William Hamilton's [10] paraphrase of it,—"Neither more nor more onerous causes are to be assumed than are necessary to account for the phenomena."[11]

The rule thus leaves a place, and often a large place, for mental construction; but it lays upon that process the rigorous requirement of proving its necessity. For example, shall we believe in the presence of a special vital force in living things? Yes, if such an existence is necessary to explain the phenomena of life; no, if, as seems to be the case, those phenomena can be explained by means of more familiar and better attested forces.

Parsimony evidently makes for scientific *simplicity*. By its exclusion of the needless, its sweeping away of fanciful and pet interpretations, it tends to keep the subject-matter of science as simple as the conditions allow.[12] It makes also for an increasing *unification* of scientific conceptions. As old causes, once predicated to account for phenomena, are found in the advance of discovery to be no longer needed, since the activity for which they stand can be re-

[10] Hamilton, Sir William (1788–1856), a prominent Scottish philosopher, was for many years a professor in the University of Edinburgh.

[11] Quoted by Karl Pearson, "Grammar of Science," p. 393.

[12] Hence it has been nicknamed, "Occam's razor."

garded as part of the working of a more widespread cause, they are deposed from their places in the scientific pantheon, and only the greater ones and their interactions remain. Thus centrifugal force has long ceased to be an actual existence for the physicist, the original impulse, conditioned by the constant centripetal influence of cohesion or gravity, being sufficient to account for centrifugal phenomena. The effect of such elimination of needless agencies is to leave the world with a smaller number of forces and to endow these with a larger number of relations, which is evidently a unifying movement of thought.[13]

Fallacy of Reification—The neglect of the principle of parsimony obviously leaves an open door for divers errors. One of these is the common fallacy sometimes called the *reification of abstractions*.[14] It consists in making an abstraction from objects of perception and erecting that abstraction into an existence by itself. The simplest example of it is

[13] In Descartes' famous rules of method the fourth and last run as follows: "In every case to make enumerations so complete and reviews so general that I might be assured that nothing was omitted." To the modern reader this formula seems to stand for that patient thoroughness, that insistent comprehensiveness, which is so characteristic of the true man of science. Read in this way, it may be considered a corollary, and an important corollary, of the principle of positivism; for if a construction of the facts is to be admitted as true when it is required by the facts, and only then, it is certainly of first importance that all the facts should, if possible, be in evidence. For the author of the rule, however, its principal meaning seems to have been a kind of inductive or analogical preparation of the subject-matter for intellectual intuition.

[14] Stallo's term. This is the real object of criticism in Berkeley's well known argument against abstract ideas. Cf. "Prins. of Human Knowl.," Introd.

the earlier nature divinities of the classic world. In ancient Rome every natural process which bore seriously upon human life was conceived as a distinct superhuman existence, or god, whose nature and reason for being were merely the maintenance of that particular process. Thus the god Janus was a deification of the process of beginning; and since every undertaking must have a beginning, he was a god of universal activity and importance, and in new enterprises was invoked even before Jupiter. So there were special gods for producing fertility, both in the earth and in animals. There were lares for protecting the house externally and penates for guarding its store rooms within; and there was a goddess, Vesta, for maintaining the fire on the hearth. When silver coinage was introduced, a separate (and new) god, Argentinus, was conceived to preside over it, just as Æsculanus presided over that of bronze!

In our own day educated men who would smile over this ancient anthropomorphism not infrequently fall into the same sort of error. They speak of "nature," "natural law," "evolution," "gravitation," etc., *as efficient agencies*—not mere abstractions, or convenient short-hand terms for aspects or groups of phenomena, but objective, controlling existences. Properly such a phrase as "the attraction of gravitation" is a mere figurative term to describe the fact that all material objects tend to move toward each other at a definite accelerating rate, and with a force that varies inversely with the square of the distance. As such it is perfectly proper;

but if one thinks of the "attraction" as an existence by itself, *an agency acting upon objects* and *producing* the phenomena, it stands for merely one hypothesis among others, and a very doubtful one at that. By the principle of parsimony it is to be denied recognition as truth or knowledge, and the fallacy of reification is committed when that principle is ignored in its behalf. It can hardly be urged too insistently that the most useful abstractions turn into pit-falls when they are reified—regarded as efficient entities.

Philosophic Positivism.—The positivism just described is that of science. The term, however, is often used in a philosophic sense for which there is far less justification. Philosophic positivism is more than a rule of thought procedure; it makes a broad affirmation regarding the nature of the world, which, if true, must be either an empirical principle or a postulate. It declares that certain kinds of existence—forces, minds, etc.—and certain kinds of relations,—causation, for example,—are *unknowable*. David Hume,[15] the chief of the British empiricists, is a radical representative of this way of thinking. He held that mental constructions are valid in mathematics, because there we are dealing with hypothetical (that is, imaginary) objects; but that in

[15] Hume, David (1711–1776), was a great British (Scotch) philosopher and historian. His was one of the keenest and most analytical minds the British race has produced. He found much difficulty in securing a hearing from his contemporaries, but his influence upon subsequent psychology and philosophy has been immense. Prejudice still attends his name because of his supposed opposition to religion, a prejudice which is generally banished by a larger acquaintance with his kindly personality and genuinely inquiring mind.

physics, biology, etc., they are purely subjective—mere opinion. The mind cannot create or increase knowledge of nature.

Hume thus impeaches all synthetic thought processes in relation to actual existences, or "matters of fact." Facts are not only primary in knowledge; they are the whole of knowledge, for knowledge is awareness of objects, and natural objects can only be discovered, not manufactured. All the interpretations of such objects made by our minds are, like atmospheric effects upon distant features in the landscape, no part of the things themselves. They may have practical value as hypotheses, working rules, etc., but they are not knowledge. Knowledge, for Hume, is a perpetual succession of distinct ("loose and separate") events or objects which he calls "impressions." These are substantially what we have called facts. "Every distinct perception," he tells us, "which enters into the composition of the mind is a distinct existence." [16] Ideas, that is, memories and so forth, are allowed to have standing as knowledge just so far, and only so far, as they are "copies" of prior impressions. Whatever actual connections between these impressions there may be, such connections are never objects of knowledge.

In the case of Franklin's thunder-storm experiment Hume would say that what Franklin really knew was the dark, surging clouds, the flashes of light and crashes of sound in their direction, the kite and its cord, with the sparks from the key, and the Leyden jar with its similar sparks. Franklin's

[16] "Treatise," I, 4, VI.

inferences that the sparks from the key came from the storm-cloud, that they were of the same nature as those from the jar and as the lightning flashes, and that all of them were caused by a mysterious somewhat called electricity, would by Hume be denied all claim to knowledge, because they are not things which can be perceived, but constructions of the mind. "The particular powers," he says, "by which all natural operations are performed never appear to the senses." [17] "The understanding never observes any real connection among objects." [18] To the natural inquiry why we all believe so firmly in connections of causation between objects, he replies that it is due to our governing principle of habit, the mind being "carried by habit, upon the appearance of one event, to expect its usual attendant, and to believe that it will exist." [19]

This is acute criticism. Psychologically it is valuable, and has had much influence upon subsequent thought. Logically it is extremely rigorous, impeaching most of our knowledge of nature. It seems to be open to exception in at least two respects: (1) Hume is evidently in error in declaring that relations are never preceived. As Professor James has pointed out [20] relations of some kinds—of space (local signs), of time (temporal signs), of tendency, etc.,—are included in probably all our percepts, constituting what he calls the "fringe" of the object as perceived.

[17] "Enquiry," Sec. 5, Pt. 1.

[18] "Treatise," I, 4, VI.

[19] "Enquiry," Sec. 7, Pt. 2.

[20] "Principles of Psychology," I, p. 243 ff.

We cannot see an object without perceiving something of its position as regards other objects. Even a distant light surrounded by utter darkness has a position relative to the beholder. (2) Then, logically the doctrine proves too much; for, if this "fringe" be sheared off, as an illegitimate, mind-added appendage, it becomes impossible to find anything in our experience which answers to the required description of knowledge; anything, that is, which is a real awareness of an object and yet free from additions due to the mind's habit of being aware in the present so far as possible in ways like those of the past. Where in actual experience is the pure "impression" of Hume to be found, the simple sensation devoid of associative additions? The objects most likely to answer to this description would seem to be the seeing of an elementary, homogeneous color or the hearing of an unvarying sound; but careful introspection shows that in the simplest of such experiences there are present other elements than the pure color or sound sensation. For example, there is quite sure to be present a noting of differences of intensity, and even if none such are discernible, the interest in the search for them is present, indicating that the sensation is being judged by more or less similar or contrasted sensations in the past. More significant still, perhaps, is the fact that the nearer we get our sensations to the nude condition of fringelessness, the more the cognitive, or perceptive, character departs from them; and they sink toward the level of unconscious dynamic reactions, not very different perhaps from those of chemistry. A sound, for example, which does not vary and is without suggestions of interest easily sinks below the level of consciousness; that is, we cease to hear it. The logic of Hume's doctrine would thus require us to identify knowledge with cerebral reactions of which we are unaware, that is, know nothing! In the face of such a *reductio ad absurdum* we must adopt a less extreme view; we must, if we are to have any knowledge at all, include in knowledge the results of the mind's synthetic processes when these have been carefully guarded. We must regard knowledge, not as a simple, irreducible datum, but as a compound of present experiences and revivals of and abstractions from past experiences. In other words, as already maintained,[21] we must recognize in it two, or three, factors, namely, (1) facts, or concrete items of experience; (2) general ideas which the activity of the mind, both analytic and synthetic, has derived from previously known facts; and, in case of need, (3) concrete ideas, such as electricity, which the mind has constructed—subject to the law of parsimony—for the explanation of the facts.

With this conclusion we are thrown back upon the conclusion that scientific, not philosophic, positivism, is, so far as it goes, the true safeguard of constructive thought; that is, that facts are the primary and authoritative elements in knowledge, but that the mind may validly make connections between the

[21] Cf. p. 53 f, *supra*. As intimated before this division is not ultimate, the psychologist analyzing the facts also into (a) simple psychical reactions, or sensations, and (b) a complex mass of revived sensations which are unconsciously fused with the former.

facts, and even posit purely theoretical existences, when such additions to the facts are required for their explanation.

Exercises

1. Describe in detail five examples of violation of the principle of positivism in old-time scientific teachings about nature. (The first third of A. D. White's small essay on the "Warfare of Science" is one source from which examples may be drawn).

2. Criticise from the point of view of the Law of Parsimony the confident conclusions as to the nature of God of some theologian of the traditional school, comparing his argument with that of J. S. Mill in the latter's essay on "Theism," pt. 2. (Cf., for example,

(1) Wilhelm and Scannel "Manual of Catholic Theology" I: II: ch. I, secs. 56, 57;

(2) Charles Hodge, "Systematic Theology" I: I, ch. 5, secs. 1 and 4;

(3) W. G. T. Shedd, "Dogmatic Theology," I: pp. 338-361;

(4) Miley, "Systematic Theology," I, pp. 161-173.)

3. A. Point out in detail three or more clear cases of the fallacy of reification in ancient views as to the origin of the universe. (Cf. White's "History of the Warfare of Science with Theology,"—the larger work—I, pp. 1-18)

B. What ground is there for the claim of the opponents of psychophysical parallelism that the theory called by that name is a case of reification? (Cf. (1) Stout's "Manual of Psychology," chap. 3, and (2) Paulsen's "Introd. to Philos." I, chap. I, sec. 5).

4. Make a careful abstract of Hume's "Enquiry concerning the Human Understanding," secs. IV and V, bringing out clearly the argument on which he bases his philosophical positivism.

CHAPTER IV

SCIENTIFIC ANALOGY

We have seen that the second kind of knowledge material consists of *general* ideas, such as inertia, and the third of *concrete* ideas, atoms, for example; and that the primary rule of sound knowledge building is that these materials are to be used parsimoniously. Often, however, there are two or more interpretative ideas which may be combined with the facts to explain them. In such cases how shall we choose? When sea-shells are found in the rocks on hill-tops, shall we say that their position is due to a freak of nature, or to the fact that those rocks when in their soft, formative condition were under salt water?

It will be seen that this question, *what kind* of interpretative ideas to use, is of scarcely less importance than the question *how much* to use them; for generalizations from past experience may be useful factors in constructing knowledge in one field and yet be quite misleading in another. The alchemists pointed out that the sunshine transmutes hard, little inedible globes into luscious fruit. When they proceeded further to argue that there must be a way of transmuting base metals into silver and gold, since the precious metals were evidently only another kind of nature's completed fruits while iron and lead were the same in unripe condition, they were using an idea, that of development, which is sound and useful in the biological field, but which they had no reason to think applied in the field of metallurgy. So, when medieval observers called the sea fossils on hill-tops "freaks of nature," they were importing into the geologic field a principle (caprice) drawn from human conduct, and which appears to have no proper application there. Many illustrations of this error might be given from the theories of natural process set forth by theologians.

To-day we wonder that men of intellect in former times should have been content with such explanations. How could Plato [1] and Kepler have believed that working secrets, or dynamic keys, of nature were to be found in certain symmetrical numbers? Unfortunately it has been much more common to disparage the science of the past and to stigmatize its explanations as artificial, superstitious, or childish[2] than it has been to mark the precise point where

[1] Plato (427–347 B. C.) was an eminent Greek philosopher, one of the three ancient metaphysicians who have influenced the world most, Democritus and Aristotle being the other two. He was the loving disciple and eulogist of Socrates, but a man of much greater range of thought than the latter. His influence is still potent in many ways in thinking men. He stands especially for two great convictions: (1) the objective reality of supremely excellent (perfect) and external types of existence, types which are always drawing lower forms of existence toward themselves, and (2) the power of the human mind to discover these supreme types by intellectual intuition, with a secondary aid on the part of the senses. Aristotle was his greatest pupil.

[2] Cf. Williams, "Hist. of Science," I, p. 294 f; II, p. 3 f, 81 f.

old-time interpreters left the path of sound natural inquiry. That point seems evidently to be *the confident, and often authoritative, use of interpretative ideas that were not drawn from the field of the inquiry itself;* that is, the use of analogy which was not scientific, because it was imported *without need* from another department of knowledge.

It is sometimes said that nature must never be explained by human analogies; but this is too sweeping a statement, for, after all, man and all his activities are parts of nature.[3] Neither is it, on the other hand sufficiently rigorous; for principles drawn from one field of *physical* science may not be applicable in another. The principle of friction appears to be entirely valid in the field of molar physics, but the physicist is obliged to discard it when he enters the molecular domain. His best hypotheses as to molecules and atoms are brought to ruin, if he yields to friction in the field of moving molecules the place of power which it occupies in the field of moving masses.

The true rule is that *interpretative ideas should be relevant*; that is, they must either be drawn directly from the field under investigation, or be proved to hold good there by coercive evidence.[4] Thus, it was an entirely legitimate process of thought when the idea of evolution was used to account for the origin of species. Evolution, that is, development

[3] It is not improper, for example, to interpret animal intelligence by human when proper allowances are made.

[4] This seems to be what Whewell had in mind in a partial way in maintaining that interpretative ideas should be "appropriate to the facts."—"Inductive Sciences," I, p. 81.

dominated by heredity but with modifications, was known to obtain in the organic field among individuals; all living things *grow* (i. e. develop) in typical ways; and so it might well effect the racial type, also. It is a much more dubious matter when the evolutionary idea is applied to the changes which have taken place in the earth and the solar system. Again, a wall of stone found in a newly discovered land might properly be explained as the remnant of a dwelling, a storehouse, or a fort, as the case might be, if the parts were so shaped and fitted together as to indicate human construction; but such an explanation would be inadmissible if neither in it nor in other parts of the country were there good indications of human agency. It would not even be permissible, supposing the wall actually to serve as a barrier against the encroachments of the sea, to conclude that nature erected it for that purpose; for the whole idea of shaping objects to serve certain foreseen ends (teleology) is one that is derived from human—and possibly organic—processes, not from what goes on in the inorganic world. Most of the older teleogical arguments of theological apologists violate this principle. When it is said that the shape of a horse's mouth shows that the animal was designed to be subject to the bit, an interpretative idea drawn, not from biology as it should be, but from human civilizing activities is transferred to a field where it has no accredited standing. Before such an interpretation could be accepted, it would have to be shown by adequate proofs that (1) organic processes work toward *foreseen* ends, and (2) that the subjection of the lower animals to human uses was one of those foreseen ends.[5]

It may be objected, that when investigation enters upon a new field, it is impossible to interpret the new phenomena by ideas drawn from it, for such ideas cannot exist until it is better known. Such, not long since, was the case as regards electricity. It was called a fluid, using an idea drawn from the field of hydraulics, because that was the conception which seemed most likely to throw light on the new phenomena. The exception is well taken; science does indeed often have to work with ideas of uncertain applicability. The investigator, however, has learned to observe the spirit of the principle under discussion, even when he departs from the letter of it; for he is careful to treat such borrowed ideas *tentatively*, and to regard them as *symbolic*, that is, as standing for an order of things largely unknown, but, as he hopes, soon to be discovered. So used, that is, in an essentially experimental way, or as working hypotheses, ideas may be transferred to new fields with profit; for then they are applied no further than their actual service justifies, and their application is a flexible one through which they become more and more modified as the new phenomena are brought to light. Indeed, any idea whatever, even the most anthropomorphic, may legitimately be utilized, if it works, provided it is applied sugges-

[5] Cf. Hegel's denial that the fact that corks make good stoppers for bottles is proof that the cork tree exists to serve that end. The teleology referred to above is the traditional sort. That there may be a sound teleology is not disputed.

tively and not dogmatically, that is, as a possible not a binding interpretation, as a hypothesis not a law. These concessions do not do away with the principle of relevant interpretation itself, for in the competition of hypotheses those are always to be preferred which seem to be most germane to the field so far as it is known; and more and more with the advance of discovery does it always become clear what general principles belong to that field, and what are to be challenged when brought to its borders.

The fallacy of irrelevant interpretation, or imported principle, is, of course, not confined to the theologians. Physicists, when they get over the border into philosophy, are perhaps as liable to it as any. The age-long insistence that the true key to the universe is the principle of inertia, taken in its original sense of powerlessness, is a case in point. Inertia, or rather inertness, is no doubt a very useful principle in the domain of mechanics, whether human or natural; and it serves well the purposes of that science which is so largely made up of abstractions from mechanics—mathematics. But when, as has been done times without number by a natural but not logical consequence, the attempt has been made to apply it in a sovereign way to the whole of existence, and to establish the amazing proposition that this living, pulsating, growing world is merely a continually shifting series of geometrical groupings of inert (dead) elements—things which do nothing whatever, except as they are made to do them, and yet which are subject to no reagents to make them do anything except each other!—then we have unscientific analogy invading the field of molecular physics. Such a staggering conception would, of course, never have gained its long hold on philosophic thought but for the strong impression of inertness made upon us by ordinary *inorganic masses;* but scientifically that is no sufficient reason for enthroning inertness in quite different fields, either in the *organic* realm on the one side, or on the other in the *molecular*, where masses are secondary, not primary.

Scientific analogy is then a principle of rigor in thought constructions. Its purpose is to shut out misleading forms of synthetic thought. It requires that, whenever possible, phenomena shall be explained by ideas known to prevail in their own fields; and that, when these are not available, ideas borrowed from other fields shall be used cautiously and symbolically, pains being taken to modify them in their new application as the facts may require.

Agreement.—Another application of the principle of rigor is the familiar logical test of agreement *negatively* applied. No would-be law or other construction of experience, can be accepted unless, (1) it agrees with itself—is self-consistent,—unless (2) it agrees with the facts in an all-round way better than any other interpretation, and unless (3) it agrees with the accredited truth already in possession. It must be confessed, however, that this third demand is not absolute. A new interpretation sometimes prevails notwithstanding it conflicts with accepted principles. In such (essentially revolutionary) cases it yields a more complete understanding of the whole wide field, and in consequence displaces the older views. Such was the case when the Copernican astronomy displaced the Ptolemaic, and when Darwinian evolution displaced special creationism.

Descartes' First Rule.—Still another sound rule of rigor is embodied in the resolve made by Descartes, "Never to accept anything for true that I did not clearly know to be such, . . . and to comprise nothing more in my judgment than what was presented to my mind so clearly and distinctly as to exclude all ground for doubt." He was led to frame this rule by discontent with the teachings he had received in the ecclesiastical schools. "I thought," he tells us, "that I could not do better than resolve at once to sweep them wholly away, that I might afterwards be in a position to admit others more correct, or even perhaps the same when they had undergone the scrutiny of reason." To his mind, with its large mathematical powers and strong interest in mechanics, the cardinal error of the scholastic teaching was its disposition to posit things of which neither could a definite image be formed nor binding logical relationship be affirmed. In reaction from such indistinct and unreal conceptions, he adopted the rule quoted above. The significance of his principle on its positive side will be considered in the next chapter. On its negative, or rigorous, side it is a sound and valuable methodological principle, one which to-day is instinctively followed in all inquiries which deserve to be called scientific. Its effect is to exclude interpretations that are vague, undefined, and beyond analytical inquiry and verification. A very large part of the erroneous thinking of the world is obscure thinking, its objects appearing as through a mist, and the relations between them at various points failing to appear at all. To obviate this source of error Descartes' first rule demands that conceptional candidates for approval and adoption—that is, logical constructions—shall come out into the light where they may be scrutinized.

Exercises

1. Make an abstract of one of the older standard teleological arguments, and point out in detail the difficulty that scientific thought finds in them. (Cf., for example, (1) Paley, "Natural Theology," chaps. 1–3;
   (2) McCosh and Dickie, "Typical Forms, etc. in Creation," I, chap. 2, sec. 3;
   (3) Kirby, Seventh Bridgewater Treatise, chap. 3.)
2. In connection with the many efforts that have been made to explain gravitation by means of the pressure or impacts of some external substance on the material molecules—that is, by means of the familiar mechanical processes of masses of matter—show how the principle of scientific analogy is disregarded.
3. Show how materialistic writers in their teachings regarding mental phenomena at times use unscientific analogy. (Cf., for example,
   (1) D'Holbach, "System of Nature," chaps. 2 and 9;
   (2) Lange, "History of Materialism," II, pp. 97-100;
   (3) Paulsen, "Introd. to Philos.", I, chap. I, sec. 4.)

CHAPTER V

CRITERIA OF TRUTH

The various principles mentioned so far, from positivism to clearness, are all principles of rigor, tests of truth in a *negative* way. Their main purpose is to show what kinds of mental synthesis are *not* trustworthy. When we ask for *positive* tests—criteria for deciding what constructions may and should be accepted—the answers are much less confident.

How, for example, should we regard the electronic theory of matter? A recent advocate of it tells us that it "accounts for static electricity, current electricity, magnetism, the radiations of light, X-rays, etc., inertia, chemical action, the atoms of matter and their peculiar properties as exemplified in the periodic law, and the phenomena of radioactivity." [1] Moreover, "the whole mass of matter may be accounted for on the supposition that it is electrical in origin." That is, the theory agrees on a remarkably wide scale with the facts of physics. Does he therefore claim that it is proved? On the contrary, he confesses that it is not proved; and adds that "the acceptability of the hypothesis depends on the extent of its *exclusive* power to account for things; the more exclusive it becomes the more

[1] R. K. Duncan, "The New Knowledge," p. 187 f.

we shall believe it." (Italics mine.) Its chief shortcoming he finds to be the fact that, "there are phenomena which the theory does not yet explain," positive electricity, for example. Nor does it account for gravitation, still less for life and mind.

It appears from this (representative) example, that (1) on the positive side, a widespread and superior agreement with the facts is sufficient ground for accepting an interpretative idea as a *hypothesis*, but not as a law or established truth. Furthermore, (2) "the more exclusive it becomes" in its power to account for things, that is, the more the facts seem to *require* it, the greater our rightful confidence in it. In this way the hypothesis becomes converted into an *accepted theory*, as was the case with the idea of evolution in biology. In such cases we may say that the factor of necessity, emphasized in the law of parsimony, has come in to reinforce that of agreement.

Not even yet, however, do we reach scientific certainty; for just as agreement alone yields only probability, since there may be unknown factors which will not fit into the hypothesis, so necessity (of this sort) yields only a higher degree of probability. It still remains possible that the demand of the facts for the explanation in question may disappear with fuller knowledge. The luminiferous ether—a universal somewhat that is weightless, frictionless, and yet rigid (a quasi-solid)—is a theoretical entity which has long been accepted on the ground of necessity; but to-day physicists are beginning to regard it with suspicion.

(3) *Experimental verification* is, of course, an es-

tablished test of truth, and the only one which is acknowledged to have power to yield scientific certainty. Familiar as this fact is, the nature of the "certainty" it furnishes is often misunderstood. That certainty is not properly demonstrative, but practical. That is, it leads to the conviction that certain things (relations and results) *are* so; it does not make it evident that they *must* be so, that nothing else would be conceivable. In ordinary induction we first form a generalization or hypothesis which agrees with all the facts so far as known. Next we deduce from it new results which should appear under suitable conditions. Finally we supply the conditions, and if the expected new phenomena are forthcoming, we count the hypothesis true. But why? Just because it works; the things which it says nature will do for us are actually done for us by nature. It is a prediction which comes true. It is a fruitful conception, an interpretation which leads to new discoveries, that is, to new experience of the kind required by the interpretation; therefore it is a truth.[2] Now, the nature of truth is sharply

[2] This test is sometimes challenged as not conclusive. It is urged that erroneous theories may lead to new discoveries. The single and the double-fluid theories of electricity cannot both be true; yet they have both proved fruitful in the way of new discovery. The criticism seems to apply only to loose statements of the test under discussion. Newly discovered phenomena do not establish a hypothesis unless they are suggested and logically required by it. Any hypothesis acted upon will lead to some kind of discovery, generally to the discovery that the hypothesis is wrong. Furthermore, in most hypotheses there is a considerable symbolic element, which is a useful vehicle for thought, but is negligible in actual thought constructions. Thus the Alexandrian astronomers, in

debated in philosophy, but for the average man of science it seems to be substantially those conceptions, or mental constructions, which enable him to predict what will happen in nature, and, within the limits of human powers, to control those happenings. Such conceptions are evidently the kind just outlined, the kind which experimental verification shows will *work*.

(4) To some minds, probably, there is a further reason than that of agreement for accepting the electronic hypothesis; it offers the kind of fundamental situation which to them seems likely. From the point of view of their intimate knowledge of nature, there is something self-evident in the very notion. This sort of ground of belief seems to have been Descartes' chief reliance, *when principles and not facts were in question.* In his discontent with the vague, inconclusive thinking of his time, he resorted to a provisional skepticism, and challenged all the contents of his mind. The result was that only one phenomenon appeared to be indubitable, namely, consciousness. That could not be doubted, for the

utilizing the notion of hollow celestial spheres did not mean to commit themselves to a posit of these as literal physical existences; they meant only to affirm that the moon and planets move *as if* set in such celestial spheres. So of the two theories of electricity; they are contradictory only when the symbolic term "fluid" is emphasized. If reference is confined to that term, however, the two-fluid theory has not led to new discovery. The two-fluid theory has led to new discovery only as its distinctive term has been taken as a symbol of the idea of activities proceeding from both poles, and in so far it certainly seems to be true. Nor does it at all appear how it can fail to be true just so far as the actual fruits of discovery are what it explicitly points to and requires.

very doubt was a form of consciousness. Thinking certainly went on, for the very inquiry in which he was engaged was thinking. Yet on close scrutiny the only reason why he was sure of the existence of consciousness appeared to be that it confronted him with such clearness and distinctness that he was forced to accept it as actual. From this he concluded, rather sweepingly, that he "might take as a general rule the principle that all things which we very clearly and distinctly conceive are true." [3]

It is evident that he felt—and in this respect he was again a genuine representative of modern science—that a law to be accepted as such should impress itself upon the mind by means of a certain coercive or self-evident character of its own, and that this inherent coerciveness was to be secured by a kind of inner immediate perception, or intellectual intuition.[4] Since Hume's day [5] this sort of process has been extensively impeached; and certainly in

[3] "Method," Pt. IV. It should be noted that in this famous rule Descartes uses the word *conceive* not perceive. He refers to objects of thought—principles, etc.—which appear to the mind in this distinct, self-evident way. Objects of sense were not regarded by him as ever presenting themselves in this way. Hence Jevons ("Lessons in Logic," p. 229) is wide of the mark in his objection that clear and distinct conception of gold mountains is no guarantee of their existence.

[4] The Greek thinkers generally had this view. They distinguished sharply between *knowledge* and *opinion,* the latter being mere generalizations (mostly uncritical) from sensory experience. Knowledge, on the contrary, was the result of the immediate insight of reason, and was of far higher validity. Knowledge so defined was the end of inquiry for the philosopher, and the possession of it was his peculiar prerogative.

[5] Cf. p. 52 f. *supra.*

the more complex cases, and especially in natural situations, clear and distinct perception of an alleged law or principle has not been found sufficient warrant of its truth. Thus it was long perfectly obvious to men—probably is so still to most of them—that all solid objects tend to move downward in an absolute sense, their courses being parallel; but the notion is erroneous none the less. The actual tendency is expressed by Newton's law of gravitation. Descartes himself, immediately after concluding to trust the clear and distinct, proceeds to construct a demonstration of the existence of God along such lines, which probably no man of science *as such* would to-day accept.

On the other hand, immediate awareness is unquestionably the basis of all knowledge. All sense perception, for example, is essentially intuitive. Its objects simply are what they are, and nothing more fundamental can be adduced to prove them, though they may be interpreted and modified by comparison with one another. The simpler relations between things, too, appear to be immediately given.[6] Axioms and certain mathematical situations seem to be matters of immediate knowledge. Descartes no doubt went too far in holding that intuition of complex relations, such as laws and systems, is sufficient evidence of their truth; yet it would seem that in this positive application of his first rule he has seized upon one actual, if not the supreme, criterion of truth—a certain self-evidence which even complex relations and systems often present to the clear

[6] Cf. p. 54, *supra*.

analytic insight of the trained observer of nature. Men who gain an intimate acquaintance with natural agencies—as was the case with Descartes himself—seem to acquire a habit of thinking in accord with natural processes, so that a proposed new interpretation, the moment it is made analytically clear, awakens in them a response, either of approval or denial, according as it agrees or disagrees with the kind of psychic movement to which nature has accustomed them. The judgment in such cases seems to be of essentially the same kind as that of any expert.

The Absolute and the Pragmatic.—Descartes' intuitive criterion of truth is not alone in coming short of certainty. Even the experimental test shares that shortcoming, though hardly to the same degree. It is always possible that deeper inquiry will show that the accepted principle does not "work" so well or so widely as it seemed to. Indeed, the objection is a pertinent one, that none of the critical tests offered lead to certainty, or indeed, to real knowledge. The principle of exclusive agreement, or necessity, for example, useful as it is, is only a makeshift as a test of logical construction. It never warrants us in thinking that we have reached absolute truth; for the interpretation which seems necessary, and is therefore accounted true, in the present generation, may, in days to come, be dismissed as quite needless. It is thus a principle which calls for endless correction of its results. Moreover, it admits of large differences of individual opinion in the present, since there is no agreement, and can be none, as to what interpretations are "necessary." So of the other criteria of truth; they are mere means of approximating truth, which itself in the absolute sense is never reached.

These criticisms are quite just in their way. The answer is that science has found it quite possible, and not inconvenient, to attain to increasing knowledge and control of nature without troubling itself about absolute truth at all. The truth which meets its tests to-day is sufficient for its needs to-day. If to-morrow's larger truth put a new and perhaps in some respects condemnatory aspect upon to-day's interpretations, why sufficient still, no doubt, will that larger truth be to the day thereof.

The objection just stated brings before us a radical difference in philosophic interest and outlook on the part of thinking men. For the philosopher of absolutist tendencies the goal of all inquiry is acquaintance—a quasi-photographic acquaintance—with things as they are and always were, and always will be; for he assumes, with the Eleatic philosophers of the fifth century, B. C., that the ultimate bases of existence are changeless. Only such acquaintance does he recognize as knowledge. Other constructions may be valid, that is, may work, but they are not *true*. On the other hand, men of science, whatever be their private philosophies, are content in their several fields of research to regard knowledge as an approximation to actuality, and all their efforts are bent to the task of making that approximation fuller and closer. They recognize that the work of science has always been with the partial, the approximate, the relative, and, seeing no occasion for shame over its progress hitherto, they harbor no fear for the future, should the approximate still continue to be its lot.

Not a few thoughtful men to-day go further; they challenge the traditional static assumptions as to existence, and show a disposition to regard even the most fixed and rigid types of substance and law as only relatively changeless. It is to them quite a reasonable hypothesis that both substances and their established forms of activity are the *attainments* slowly reached through the ages of an order of existence which in the remote past was more or less undetermined—a process of continuous creation, in fact, which is still going on. For the absolutist, on the other hand, there never was any creation, unless we are pleased to call by that name some of the infinite series of unfoldings of the eternal Absolute Existence or Substance. This radical difference in outlook doubtless roots in that fundamental difference in scientific interest described in the first chapter, the main interest of the absolutist being the contemplation of nature, while that of the type of philosopher just referred to is the use of natural facts and laws for progressive purposes of thought and life. The latter interest is properly called *pragmatic* when that word is taken in its broader sense.

Exercises

1. It is a generally accepted theory of psychologists that there is no psychosis without a neurosis; that is, mental phenomena occur only in connection with some neural process. Show in

what various ways this principle should be tested before it is admitted to the rank of a natural law.

2. Show in detail how the various criteria of truth are applied in the discussions of

(1) Darwin on "The Structure of Coral Reefs," chap. V; and of (2)Huxley on "Biogenesis." (Cf. "Discourses, Biological, etc.," lec. VIII).

PART II

RESULTS—EMPIRICAL PRINCIPLES

CHAPTER VI

MATTER—QUANTITY

In turning from Methodological to Empirical Principles, that is, from the thought *methods* to the thought *results* of science, only the major empirical principles can be discussed. Our concern will necessarily be simply with those large working concepts (ideas) which present-day science is continually using in its mental constructions. To consider scientific thought results in general would require a treatise, if not a library. Of course, our guiding inquiry from now on will no longer be, *How* do we know that certain things are true, but rather, *What* things does science hold to be true?

Material Things the Original Subject-Matter of Science.—It might well be very instructive if we could divest our thoughts of all the empirical teachings of science, and, looking at nature with the fresh vision of the child or of primitive man, note which of her parts or aspects appealed to us first and most strongly. It is scarcely possible, however, thus to put ourselves as observers outside the body of teachings which have entered into our make-up as observers. That would be in a sense to put ourselves outside of ourselves. But much the same point of view can be gained by noting the objects which attracted the attention of the earliest scientific inquirers. These beyond doubt, were the features of the external, or material, world, the things which appeal to the outer senses. It was not because these things were nearest to man; for generally they are not so close and vivid as his feelings of pleasure and pain and his emotional experiences; but they are more clearly defined, and at the same time more stable, and so more open to inquiry. An emotion begins to vanish the moment we scrutinize it, but a stone or a star persists in its characteristics however long it is inspected. These relatively definite, stable objects known to us through our outer senses—what we call material things, or physical objects—still constitute the subject-matter of physical science.

The Phenomena of Change the First Problem of Science.—In discussing the motives of science [1] the remark was made that to many minds the world is a drama—something of absorbing interest to be watched. Now, in a drama the interest centers on the movement, and especially the development. It was evidently this aspect of movement, the changeful features of nature,—its continual transformations, and birth and growth and death—which appealed chiefly to the first men of science. Nor is it strange that it was so. All animals, man included, maintain their life and well-being through a continuous adjustment of themselves to their environment. To do this it is needful that they be quick to discern changes in that environment. It was under the pressure of this need apparently that the knowing

[1] Cf. p. 16, *supra*.

faculties were developed. Quite naturally, therefore, an animal's attention is most readily caught and held by the changes going on about it. A lack of attention to them may cost it its food, its limbs, or its life. When man came to the stage of reflective, or scientific, interest it was but a natural continuation of his biological habit that he should give attention to the changeful rather than the static. How did water come from the air and ice from water? Why did fire spring out of the wood? Especially was constructive change, the process of becoming or development, the object of his curiosity. How did the seed build itself up into the plant and the tree? How did the egg transform itself into the bird?

Prescientific thought accounted for these phenomena *animistically*, that is, by the hypothesis of an invisible soul or spirit residing in the objects and working the transformations. It was not an absurd hypothesis, odd as it seems to us to-day; for we are aware of invisible, and to our fellows altogether imperceptible, changes within ourselves which lead to great changes in our conduct; but it has not justified itself in subsequent inquiry. A truly scientific beginning was made, and scientific inquiry may be said to have commenced, when men began to explain natural changes by means of *more familiar objects and changes in nature itself*. Of such a type of inquiry was the question of the first philosophers of Greece as to what was, and is, the original element or mother-stuff of the world. Their answers were naturally crude at first. Thales (600 B. C.) thought it was water; Anaximenes held that it was air. The great error of these men and their fellows lay in the notion—a heritage from animism—that the underlying substance of the world *alters* its inherent nature when it passes from one material form to a different one, much as a human mind seems to change in passing from one state to another. This is a magical and not a scientific conception; for, if existence can thus metamorphose itself through and through in a moment, there is no rational ground for the universal statements of science, and especially for the principle of uniformity. Anything may become anything else, however different from the former thing; and we can conceive of no reason why in the same circumstances the second thing should act like the first.

Yet most surprising metamorphoses do occur in nature. When the ancient Roman burned faggots on his hearth, the greater part of their substance did disappear mysteriously before his eyes, and the whole of it was transformed. To an ignorant but thoughtful mind it is not strange that there seemed to be something divine in the process. Whither had the solid wood gone? Up to heaven, seemed to be the answer of the ascending smoke, itself suggesting the clustering ghosts of the vanishing faggots. The world is full of such transformations; how shall we explain them? Is there no fundamental change of nature or essence in them?

Physical Objects Constant in Nature but Composite and Changeful in Structure.—No results of permanent scientific value were reached until inquirers learned to answer this question in the negative, and to say confidently that *the changes* observed, surprising as they are, *take place, not in the fundamental nature of things, but in the arrangement, movements, or number of their parts.* This involves the conception that material things are composite, that is, made up of many constituents (*not necessarily atoms*) which are so minute and so blended together as to be imperceptible to the senses. Empedocles [2] seems to have been the first to hit in a rude way upon this explanation. He thought that there were four different and changeless kinds of world material, which were combined in physical objects in varying proportions.[3] They were earth, water, air, and fire. So for him the mother-stuff of the world was four-fold instead of single—a hypothesis in which he was followed by most of the thinkers of antiquity. His great contribution to science was the thought that the varying porportions of these changeless constituents and their varying relations to each other (changes of position, etc.) account for the natural changes which perpetually take place before our eyes.

This, of course, is the working theory of physics to-day. Steam, water, and ice are not now regarded as different substances, but as different *forms* of one substance (H_2O); and these differences of form are accounted for by saying that in the ice form the invisible particles of the substance are arranged in geomet-

[2] Empedocles (490–430 B. C.), a Greek philosopher, poet, and statesman of Agrigentum, Sicily, was a man of great range of thought and of forceful personality. He is said to have posed as a prophet and magician.

[3] For example, flesh and blood were made up of equal parts of the four elements, while the bones of animals had two parts of fire and no air.

rical groups with a restricted range of movement, in the water form they have such range of movement as to be largely independent of each other, while in the vapor form their movements have become so violent as to result in continual mutual repulsions. Nor are the *constituents* of water (the hydrogen and the oxygen) regarded as having changed their fundamental nature—that is, their characteristic forms of behavior, actual and potential—on entering into the compound, or water, condition. They have only changed from one type of behavior to another, and this owing to their influence on each other. When hydrogen burns and forms water, its atoms after the union continue to exist and to possess the same possibilities as before; but, owing to the influence of the oxygen atoms to which they have become wedded, the kind of activity is different, just as a joiner who one month makes a wagon may the month following make a boat without any radical change in his own nature.

There are three distinct ideas involved in this way of thinking, ideas which are still parts of accepted scientific tradition, because they have proved the "open sesame" to the mysteries of change. The *first* is the idea of *infinitesimal, and so imperceptible, constituents*. From this we see why the processes of change are mysterious. They take place on a plane too low for the observation of our senses. The *second* is that of the constancy of nature (uniformity of behavior) *of these constituents*. This accounts satisfactorily for the fact that natural processes can so often be reversed, for example, the water formed by the combustion of hydrogen being analyzable again into hydrogen and oxygen. These two ideas are evidently perfectly distinct logically; but they cannot well be treated separately, as they involve one another. The third idea is that of *different kinds of constituents* in material things,—as sodium and chlorine in common salt—an idea which has proved very useful, especially in chemistry. Nevertheless, it is not strictly necessary for the theoretical explanation of physical changes, and as we shall see, metaphysical speculation has always tended to eliminate it. It is quite conceivable that in course of time it may be discarded as regards fundamental existence—a result which may be achieved in our own time through the electronic theory of matter. *The composite structure of physical objects and the constancy of nature of their components may thus be regarded as the oldest empirical principle of science.*

Concept of Matter.—I hardly need to add that the modern physicist does not recognize any of Empedocles' world materials as fundamental, but has substituted fourscore others in their place. These—oxygen, hydrogen, carbon, etc.—he calls *elements;* and they, together with their many combined forms (mixtures and compounds), he calls matter. In science this term matter, or "sensible substance", is simply a useful general term standing for the broad fact that the constituents of natural objects have enough in common to be classed together. It does not mean, as it does so often in philosophy, that there is a common substance underlying all the elements, a substance of which they are special forms or modes. For the physicist *as such* the common factor in the natural elements is altogether abstract. That is, they all have certain properties in common. These properties are generally reckoned to be three: *extension*,[4] *gravitation*, and *inertia*. Whatever objects possess these three properties are material; whatever objects do not possess them are immaterial. Thus thought is clearly immaterial, since it neither occupies space nor possesses (literal) weight and inertia. The luminiferous ether, however, which has extension and inertia and lacks only weight, is generally regarded as quasi-material.

(1) *All material things are extended*; they occupy space. This is one of the chief traditional distinguishing marks of matter. To-day, however, it is less universally affirmed than formerly, that is, as a fundamental distinction. There is quite a tendency now, especially among those holding the electronic theory of matter, to regard extension as largely the effect of an activity which is more fundamental than itself. Sir Oliver Lodge, for example, suggests that the electrons which constitute an atom may bear about the same relation to its "otherwise empty region of space" that a few thousand printer's periods in lively motion would bear to the space in a public hall; they may occupy the atom "in the same sense that a few scattered but armed soldiers can occupy a territory—by forceful activity, not by bodily bulk."[5] On this view the extension of mat-

[4] This is more properly to be called *exclusive extension*, for the notion of impenetrability is always, though generally not explicitly, associated with it.

[5] Smithson, Inst. Rept., 1903, p. 231.

ter as evidenced by the senses is evidently the effect of kinetic energy; it is a dynamic manifestation. This conclusion is not dependent upon the electronic theory; the unquestioned phenomena of expansion and contraction, elasticity, porosity, etc., point in the same direction.

(2) *All material things have weight*, or (the same thing) display gravitation. This is still a mysterious phenomenon; but we can at least say of it that it, also, is a dynamic property, a manifestation of force. Moreover, as we know that natural forces are correlated, that is, transformable in precise equivalents into one another, this property of gravitation seems to furnish a distinction of *convenience* rather than of essence. It is far from being the only activity, or dynamic property, of matter.

(3) If Gravitation is mysterious, *inertia*, the third mark of matter, is more so. It seems to be the very core of the concept of mass, and is even more universal than gravitation. "So far as is known [it] is the only property common to all kinds of matter which is absolutely permanent and unchangeable in amount in a given isolated portion of matter." [6] In physics the term inertia is not used in the literal sense of inaction and incapacity for action. The mechanical, and still more the molecular, activities of matter are too manifest for such a conception. The inertia of physical science is defined as "the property in virtue of which matter cannot of itself change its own state

[6] A. S. Kimball, "College Physics," p. 18. Cf. R. K. Duncan, "The New Knowledge," p. 179, "The one sole unalterable property of matter is inertia."

of motion or of rest."[7] At first thought it seems to mean merely that material things are destitute of initiative; they cannot bring about changes in their own condition. But that is by no means all; for the authority just quoted immediately adds, "The inertia of a body is the resistance which it opposes to any change of its state whether of rest or motion." Inertia, then, stands for resistance, opposition to and absorption of interfering force. This is evidently another dynamic property. It is conceivable only on the view that the "inert" body is already doing something—evident enough in such cases as a flying cannon shot or a revolving wheel—which it tends to persist in doing, and which the interfering force must overcome if it is to effect any change. Thus, despite the original sense of the term, inertia does not mean that matter is inactive and idle, but simply that it is persistent in whatever type of activity it takes up. It will be seen that for present day thought all three of the distinctive characteristics of matter indicate that its essence is dynamic, or energetic. To this idea we shall have to return.

Matter and Mass.—The discussion of matter above, it should be noted, is not, strictly speaking, concerned with a scientific principle, but with a scientific *concept*, or general working idea. The formation of that concept, however, was a scientific achievement of first class importance; for concepts bear the same relation to principles that terms do to propositions. The significance of the idea of matter will appear more clearly if we compare it with the

[7] "Ganot's Physics," p. 13.

mechanical conception of *mass*, which some physicists are disposed to substitute for it, doubtless because the latter is a more technical term. Mass likewise stands for a common core of properties possessed by all material or physical objects; and as a matter of fact those properties are the identical three which we have found to be the marks of matter. By mass is meant the *quantity of existence or substance* [8] and the formula of that quantity is the bulk (volume) times the density. Now, bulk is evidently the property of extension, which, as we have seen, distinguishes matter. Density is some function of energy, expressed either positively in terms of weight (the force it will exert), or negatively in terms of inertia (the force it will resist and absorb); and these are the other two differentia of matter. It might seem then that matter and mass are synonymous terms, and indeed they may often be treated as such. Yet there are differences between them which should not be overlooked.[9] They were formed under diverse influences. Both are, of course, abstract terms. Science does not think of either matter or mass as existing by themselves, that is, apart from the sensible objects which possess the properties they represent. But matter, when transferred to the field of philosophy, may properly enough become the name for a theoretical existence—a universal underlying substance—which is regarded as an actual existence by itself. Mass,

[8] Cf. the definition of "Ganot's Physics": "The mass of a body is that which remains unchanged, in all the transformations which the body may undergo."—18th ed., Sec. 26.

[9] Cf. Ward's "Naturalism and Agnosticism," I, p. 57.

however, remains persistently abstract even in philosophy. The reason seems to be that in the sense in which it obtains in physics, it is a term framed for the purpose of representing, not *all* the properties common to physical objects, as was the case with the scientific term, matter, but of representing just those properties of them which belong in the field of mechanical physics. As we have seen the properties *happened* to coincide with those represented by the older term; but apparently it need not have been so. It is quite conceivable, for example, that chemical properties might have been found which characterized all material things but which were not sufficiently mechanical to be included in the connotation of the term mass.

Principles of Matter.—The scientific principles connected with the concept of matter belong in the main in a text-book on physics, not in one on science in general. Three of the most universal, however,—three connected more or less with ideas already discussed—must be mentioned here.

That *matter is transferable* is one of these. Though matter occupies space, and does so in the exclusive way which we call impenetrability, yet it lays no claim to any particular space, but can always be shifted from one place to another by the exertion of sufficient force, as railroads, and steamboats, and all means of transportation bear witness. Indeed, so far as our acquaintance with matter goes, it is always changing its location. Science discovers no object that is absolutely at rest.

Matter is also mutable. Objects of sense change their aspect, often most surprisingly, albeit their elements do not change fundamentally. When different elements combine, there appears to be no limit to the possible transformations. Man finds himself in this respect able to supplement nature, and produce new combinations—explosives, flowers, animals —which she never dreamed of. But even without new chemical and biological combinations the transformations of material things are most remarkable. It is the same substance (H_20) which now makes up the fairy creations of frost and snow, and later dances in mountain streams or rages in ocean storms. At one time it floats peacefully across summer skies; at another it toils as a captive titan in man-made engines, or bursts furiously from the torn vents of active volcanoes.

The third principle is that of the *indestructibility* or *conservation of matter*. This is properly a metaphysical principle, for no human instruments or powers of perception are sufficiently fine to establish it experimentally. Yet scientific experience, at least up to the time of the discovery of radium, was all in the direction of confirming it; so that it has long received almost unchallenged acceptance. We cannot conceive of fundamental existence either coming into being or passing out of it. To primitive man, indeed, just that sort of thing seemed to be taking place continually; but when it was perceived that the seeming annihilations might be only changes of structure, and so of appearance, and still more when in a multitude of such cases—as in the burning of an object—it was shown that the total mass apparently remained unchanged, then the mind's native tendency of thought carried it irresistibly to the conclusion that matter, with all its wonderful mutability, is indestructible and uncreatable, and consequently constant in quantity.

The phenomena of radio-activity seem at first thought to impeach this long established principle; for in them we seem to have cases of actual degeneration of matter, cases in which part of the material substance disappears in the form of free energy and ceases to be. Yet probably no physicist considers that the core, or real purport, of the principle is affected by these new discoveries; on the contrary he feels as confident as ever that the sum total of fundamental existence, either as matter, energy, electricity, or what not, is a constant quantity.

Further Simplification Speculative.—Reference has been made [10] to the fact that while the idea of the essential unlikeness, or heterogeneity, of the physical elements is the working basis of physics to-day, yet in the end it may not prevail as regards fundamental existence. This may come to be viewed by philosophy, and perhaps by science, as essentially homogeneous. Hitherto, however, the many attempts which have been made to establish such a conclusion have come to naught. In both ancient and modern times strenuous metaphysical efforts have been made to analyze the elements[11] in thought, and reduce them to different combinations of one underlying simple substance, itself everywhere alike.

[10] Cf. p. 85, *supra.*

[11] If this were done, the term element would, of course, no longer be accurate.

If an intelligent observer who knew nothing of china-ware came upon a fine display of such goods, he might be chiefly impressed at first with their variety and beauty. In time, however, their similarity and texture would be likely to impress him, and he would probably come to the conclusion that they were all made of the same material, a conclusion in which he would be quite right, for glazing and decoration aside, they are all made of one stuff—clay. The atomic theory of Democritus[12] and Epicurus[13] was an attempt to find this fundamental clay of which all things are made in tiny *indivisible* blocks, infinitely varied in size and shape but homogeneous and simple in nature, blocks which are characterized by but one active property, exclusive extension, or impenetrability. Aside from extension, literal inertness was their prime characteristic.[14]

[12] Democritus (460–357 B. C.) of Abdera, in Thrace, was the greatest of the ancient atomists. He was called the laughing philosopher because of his cheerful outlook upon life.

[13] Epicurus (342–270 B. C.), also a noted atomist, modified (and marred) the atomic theory of Democritus, and joined to it much of the Cyrenaic doctrine that pleasure is the only possible end of rational action.

[14] This statement probably does not apply fully to Democritus, who seems to have regarded his atoms as possessing also inherent motion —a richer and, of course, less simple conception. The student should distinguish carefully between the traditional, metaphysical doctrine of atomism referred to above, the primary ideas of which are indivisibility, homogeneity, and inertness, and the modern chemical theory of atoms which dates from the time of Dalton. The latter requires neither indivisibility nor inertness, neither homogeneity nor simplicity. It is the doctrine that existence, so far as it is known to be efficient, occurs in the form of more or less discrete, infinitesimal units of one kind or another; and it explains so many phenomena, brings so much unity into our knowledge, and has led to so many new discoveries, that probably no accredited physical scientist disputes it.

Plato, with his large mathematical and esthetic interest, attempted a like result by conceiving of the one simple substance, which he called non-being—really a kind of substantial space—as worked up into manufactured units of various geometrical shapes, manufactured, that is, according to an idea. As one would expect from their origin, these were not indivisible.

At the renaissance under the influence of revived Greek thought, a renewed interest awoke in the theory of the essential homogeneity of things. The character of the new discoveries of Copernicus,[15] Galileo, Kepler, and Newton, fostered this interest. They were in mechanical, not chemical, physics, and were thus concerned with the motions and quantities of things rather than with their inherent nature. The motions of the planets and the rates thereof, the speed of falling bodies, the principles of the inclined plane, the phenomena of hydraulics—all involving the fundamental laws of motion, but not differences of specific quality—these were the first fruits of the new science. In such a situation the old Epicurean theory that there was no difference in the essence of things, but that their variety arose solely from the differences of number, arrangement, and movement of their homogeneous components, naturally wore a very plausible aspect. It was adopted by both Galileo and Descartes; by the former in substantially the ancient, atomic form, by the

[15] Copernicus (1473–1543), commonly regarded as the founder of modern astronomy, was a clergyman (canon) and physician at Frauenburg, Prussia.

latter more nearly according to the conception of Plato. Descartes denied that there is such a thing as void space, and held that matter—the basic substance—is absolutely continuous (and so infinitely divisible)[16] and absolutely homogeneous. For him, as for Plato, matter is simply space, when this is regarded as, not a void, but an extremely thin substance with but the one fundamental quality of exclusive extension. Descartes parts company with Plato by denying that the particles of matter have been manufactured on any plan. For him they are accidental results of the fact that at the dawn of creation God agitated the original continuous matter, thus both breaking it up into myriads of parts and setting these in motion. The particles in their movements are subject to the control of divinely appointed natural laws. By their movements so controlled the present complex universe has been formed. This governance by natural laws is the darkest spot in Descartes' scheme, for how inert

[16] On this question of divisibility, which has been debated since the time of Anaxagoras and Democritus in the fifth century, B. C., turns the further speculative question whether existence is at bottom continuous or discrete. According to the traditional atomic view indivisibility, and so discreteness, are the foundation truths of the world. The atom is ultimate, for the very word means *indivisible.* For the Platonic-Cartesian conception, on the other hand, infinite divisibility is the ultimate truth, and all existence is continuous at bottom. The question is still open. We may think of the electrons, for example, as ultimate and indivisible—true atoms in the Greek sense—and then we hold to basal discreteness. But if, with another type of speculative physics, we regard the electrons as merely points of concentration of, and activity in, the ether, which itself is regarded as infinitely divisible, then continuity becomes the basal truth.

bits of substantial space moving because of mere blind impact can follow natural laws seem to surpass imagination.[17]

In all these theories the familiar qualities of things as we perceive them are regarded as *effects* made upon our organisms by the various combinations of the supposed homogeneous units. Thus we say that one object is red, another green, and another blue; but, we are told, the real fact is merely that the particles of these three objects are so arranged that they reflect ether waves of different lengths to our eyes, where correspondingly different effects are made upon the retina. There are certainly empirical analogies in support of their view. Glass has not changed its essence when, on being ground to powder, it ceases to be transparent, and takes on a white color; nor has water become different itself when, on being mixed with invisible air, it experiences a like change of aspect. In both cases the difference of appearance is due to a mere difference of number, arrangement, and rate of motion of the constituent particles.

The theory, if taken seriously, makes startling changes in our conception of the world around us. Instead of a teeming universe of colors and sounds, pressures, odors, etc.,—all glowing, varied, rich, and seemingly thoroughly actual—we are asked to regard the actuality of things—apart from our own peculiar ways of knowing them—as but little more than shadows of what they seem to be, pale thin ghosts of our perceptions of them. These ghosts are, indeed,

[17] The thought that divine will is constantly present to make them obey law is expressly excluded by Descartes.

wonderful in structure from the mathematical point of view; but from the empirical standpoint the swarms of infinitesimals which make them up are equally pale and thin and elusive. This difficulty, however, is by no means insuperable. Science does not assume the correctness of the mental constructions of common life—our ordinary notions of the world. The real difficulty with the hypothesis is that it does not really account for the facts. If minute bits of extension (stiff space) are to cause in us all the wonderful panoramas of color and mixtures (and symphonies) of sound, and so forth, which we call the external world, it must be because they do something—produce or reflect ether waves, for instance. But if they do anything, they are not inert, and the theory is self-contradictory. No doubt it can be amended so as to attribute to its units only a few very simple activities, such as hardness and elasticity, but recent advances in physics have shown that this concession is but the opening wedge for the entrance of the quite opposite view that activity is of the very essence of matter, and inertness and even extension but its accidents.[18]

On the other hand, when the needless hypothesis of essential inertness (literal) is abandoned, it is as-

[18] Cf. p. 69, *supra*. President Nichols speaks of the "extreme complexity of the material atom," and says that "the iron atom must be capable of vibrating in hundreds of different periods . . . swinging or bounding, revolving or shuddering. . . . Before the evidence of the spectroscope, the older idea of the atom as a simple, structureless body falls to the ground. The complexity of a grand piano seems simple in comparison with the iron atom."—Lecture on "Physics," p. 21.

suredly a possibility, and a possibility to which speculation in physics perpetually returns, that the many elements which science has discovered are modifications—evolutionary developments possibly—of one original substance. It certainly seems highly improbable that the members of the very large elemental group of metals with their many and strong similarities should be eternally distinct and ultimate. The electronic theory,[19] now in the ascendant, may yet reveal matter to us as essentially homogeneous, its various forms being due to differences of intensity and organization. Our organizing and unifying habit of mind leads us naturally to expect some such outcome. On the other hand, it is, of course, conceivable that there are eternal and absolute differences between substances, irreducible now and always.[20]

Discreteness and Continuity.—What was essentially a scientific distinction, the distinction between the discrete and the continuous, received implicit recognition very early in primitive life, and long before the dawn of science. When the patriarch Jacob sent a present to his brother Esau,[21] the description of it is simple and definite. It consisted of 220 goats, 220 sheep, 30 camels, 50 cattle, and 30 asses. No explanation of this statement is needed. But when in the next chapter he is said to have bought a "parcel" of land near the city of Shechem, the ground purchased and the price—"100 pieces of money"—are stated in terms needing definition. How much was a "parcel" of land? What was a "piece of money"?

[19] Cf. p. 125 f, *infra*.
[20] Cf. note at the end of the chapter.
[21] Cf. Genesis 32:13 f.

A shekel of silver perhaps, or some multiple of a shekel; but what was a shekel? What, too, was the need of such a word?

Why is Abraham said to have purchased the field and cave of Machpelah for 400 shekels of silver.[22] Why not for 400 silvers, like the 220 goats, and so forth, in Jacob's present? Obviously the answer is that the animals existed as separate units which could be counted, but the silver did not. In order to handle it in a way which would be recognized as equitable by the parties to the transaction, the silver had to be divided up in some artificial and conventional way, that is, weighed off into shekels, or some other unit agreed upon. In most countries to-day, for the convenience of commerce, the government makes this division, and certifies to the amount of precious metal in the separated part, or coin, by an image and superscription stamped upon it. In China, however, the old method of private calculation still prevails, and each merchant carries with him on his trading expeditions a little scales for weighing silver.[23] This need of commerce for a means of computing quantitatively objects of value which cannot be dealt with adequately by mere counting rests upon the broad fact that some things in nature [24] exist in a manifest singleness, whereas others have no regular and typical boundaries. The former are called *discrete*, the latter *continuous*, quantities.

[22] *Id.*, Chapter 23.

[23] Copper, however, is coined and is then called "cash."

[24] The distinction is equally evident in the products of human manufacture. The builder orders so many thousand brick, but so many thousand *feet* of lumber.

It is true that all things are in some measure separate; that is, they are found in masses which show much similarity of internal character, along with evident contrasts to other masses. Even rocks and sandbanks, owing to the sorting agency of constant forces,[25] are distinct from their environment, while continents and oceans, planets and solar systems, show a more evident degree of singleness, which is often loosely called individuality,[26] and which enables us to know them *as* continents, oceans, and so forth. Indeed, but for this singleness it is hard to see how knowledge of the external world could arise.

From the point of view of human need, however, this singleness is often insufficient; for full often the wholes are too large for our purposes, and we must deal with parts of them. Moreover, their boundaries are wont to be too various for the purposes of commerce, and still more insufficient for the ends of science. To purchase a stratum of rock or a river of water would be to bargain for a very uncertain quantity. Such continuous objects must have *arbitrary and conventional divisions*—perches, gallons, etc.,—*imposed upon them;* that is, the parts of them that we deal with we have to make for ourselves. *Continuous quantity may*, therefore, *be defined as* material, or sensible, *substance which can be counted,* and described quantitatively, *only after being artificially divided up*. Water and all fluids are of this character;

[25] Cf. Herbert Spencer on segregation. Epitome of Herbert Spencer's Philos., p. 53 f.

[26] This word should be reserved for types comparable with living forms.

also, stone in the quarry, coal and ore, land, electricity. These must all be separated, ideally and symbolically if not physically, into distinct parts or units before they can be described in terms of number. The fact that it is possible to agree upon standard units by means of which this separation into arbitrary parts can be effected, and adequate control of this kind of quantity secured, was, as has been intimated, an early discovery of commerce, and of commerce in the form of barter. Our most common units of measure—foot, yard (a rod or wand), mile (thousand paces), gallon (a bowl)—witness to their primitive origin. These, however, have naturally not been at all uniform, and it has been one of the major tasks of science to fix with precision these common standard units, and to devise new ones fitted for its special needs.

Discrete quantity, on the other hand, is material substance which in ordinary experience presents itself to the senses in distinct and separate items or units. Of this kind are fruits, eggs, trees, animals, and indeed all organisms; also, such inorganic objects as detached stones, islands, stars. In fact, whatever can be counted in its natural state, and the result stated with substantial truth arithmetically, is discrete.

Advanced Science Quantitative.—This distinction, though it came to scientific recognition long after it was implicitly known in the practical life of men, is yet of fundamental significance; for it nearly corresponds to the grand division of the natural world into organic and inorganic. All organisms are discrete, while in the main the inorganic realm is continuous. It is true that some inorganic objects—planets, etc.,—and many objects of human manufacture, are discrete, but most of these have some kind of organization, or purposive arrangement about them, and so are allied to the organic realm by similarity of some sort.

Furthermore, the great and fruitful *quantitative* development of science is based primarily upon the aspect of continuity which so much of material existence presents to the enquirer. Science in its elementary stage is *qualitative*—concerned chiefly with the presence or absence of qualities. But as it advances, its attempts at greater precision of observation and statement oblige it to take account of things quantitatively. It has to consider the amounts or dimensions of the objects before it, and of their functions and constituents.[27] This, of course, creates a need for accurate measurement, a need which is felt first and most in dealing with continuous quantity. Later it is discovered that even when the quantities are discrete, adequate exactness can be attained only through measurements, since the units are never quite uniform.

Standards.—Measurements to be of much value require standard units, for the great service of the measured result is in furthering comparisons between

[27] Jevons dwells justly upon the complexity of such inquiries. Regarding scientific knowledge of the so-called fixed stars, he says, "We must then determine separately for each star the following questions: 1. Does it move? 2. In what direction? 3. At what velocity? 4. Is this velocity variable or uniform? 5. If variable, according to what law? 6. Is the direction uniform? 7. If not, what is the form of the apparent path? 8. Does it approach or recede? 9. What is the form of the real path?"—"Principles of Science," p. 280.

quantities that have been measured by the same unit. Especially when the results are to receive *social* recognition and acceptance must the unit be a *standard* one, that is, one generally recognized. Such a unit may be defined as any convenient magnitude—a platinum rod, for example—which shall be agreed upon as the one in terms of which all similar magnitudes shall be described.[28] It is necessarily arbitrary, for nature does not furnish units that are constant.[29] It is an ideal of men of science to connect their standards as closely as possible with fixed natural distinctions, statements of comparative dimensions made in such terms being more illuminating, and inferences in larger number and of greater reach then being possible. The only case in which they have succeeded in realizing this ideal in connection with an ultimate standard appears to be that of angular magnitude. The total angular space in a plane about any given point, the *perigon*[30] as it has been called, is evidently a uniform quantity. In so far the standard of reference is natural, but it does not become a *standard* unit until agreement is reached as to the way it shall be subdivided—as into 360 degrees—and that is an arbitrary affair again.

The metric system is an ambitious but unsuccessful

[28] Cf. Jevons, "Prins. of Science," Chapter 14. Measurements and standards are, of course, parts of the methodology of science; but since they are not properly methods of thought, it seemed best to refer to these topics briefly here rather than to include them in part one.

[29] It may be, indeed, that the wave length of a particular kind of light and the molecular mass of some element are examples of natural units which are constant; but these are theoretical existences, not objects of perception, and so not readily available as standard units.

[30] Cf. Jevons, o. c., p. 306.

attempt to achieve a like result in the matter of a standard of length. The ten-millionth part of the terrestrial arc from the pole to the equator was selected as the standard or unit, and its magnitude ascertained by a costly trigonometrical survey. Quite naturally the computation proved inaccurate, so that the standard French meter bar is not what it was meant to be by at least one part in 5527, and is actually an arbitrary unit after all. Even were it possible to make such a subdivision with entire accuracy, a changeless natural basis for the standard of length would not be obtained thereby, for it is quite certain that the dimensions of the earth undergo change.

Measured Results Always Relative.—The numerical description of any quantity that is continuous, or treated as such, is of course expressed in terms of the standard unit. It is the statement of a ratio. This ratio, as Professor Jevons points out, often takes the form $p=\frac{x}{y}q$;[31] in which p is the quantity

[31] This is, of course, not the only form in which the ratio is expressed, as Jevons makes plain. (*O. c.*, p. 285 f.) He also describes interestingly (pp. 292 f., 296 f.) some of the ways in which objects which cannot be measured directly may yet have their movements or dimensions determined quantitatively by means of some mediating relation. Thus the time of the moon's rotation on its axis cannot be observed directly, for the features on its surface do not change position as regards the mundane observer. This very fact, however, enables us to infer that the rotation period coincides with that of its revolution around the earth, which latter is open to observation. Gold leaf, again, is not measurable in its third dimension because of its excessive thinness; but by weighing it in quantity, and by means of its specific gravity computing its net volume, and then dividing by the total area of the sheets weighed, it is possible to determine the average thickness.

to be measured and q is the standard unit. The meaning is, that the quantity in question equals some multiple (perhaps fractional) or sub-multiple of the unit. It will be seen that quantitative descriptions are necessarily relative; they refer always, not only to the subject-matter, but also to some recognized object beyond. Inasmuch as such descriptions become more and more the main objective of physical science, it is evident that its concern is with the organization or structure of the world rather than with its nature as revealed in immediate perception. In other words, it tells us *about* things but does not *present* things to us, as art, for example, seeks to do. Its aim is descriptive, not appreciative, knowledge.[32]

NOTE:—It may be doubted if the old atomic theory ever was acceptable to many minds which did not at the same time hold to theistic dualism, that is, believe in an external, personal Creator, to whose province otherwise insuperable difficulties could be relegated. For by itself the hypothesis seems quite hopeless. It offers no agency to account for the transformation of dead, inert blocks—infinitesimal brickbats—into the familiar, present day living organisms of nature. The atoms themselves are impotent by hypothesis; and to add that these impotencies are flying about at random, and so come into all sorts of different geometrical situations, is to suggest nothing more than picturesquely varying clusters of impotencies. It is as though grains of sand were represented as turning into birds and

[32] This distinction will be made clearer in a subsequent chapter. Cf. chap. IX.

horses and men on coming into certain positions relative to each other.

Those who conceive such transformations as possible fail to distinguish between conceptual and actual situations. In nature we often find groups and combinations of molecules doing things, and sometimes very surprising things, which none of the molecules do by themselves; but then in dealing with nature we make no pretense to knowing all the possible activities of the molecules, still less of knowing that they can do nothing of themselves. There may well be potencies and activities of the molecules which are quite imperceptible to us until they are either massed or brought more or less into conflict with the activities of other molecules. The philosophical atomist, however, is dealing with a purely theoretical situation, in which the quantities (the atoms) have no latent or imperceptible attributes, nor indeed any attributes whatever except those with which he expressly endows them. In such cases there is no residuum of unexplored possibility to fall back upon as the cause of phenomena which the posited factors do not warrant.

Exercises

1. Show in detail how the first material principle established by science (Cf. p. 85, *supra*), with the three ideas involved in it, serves to explain the passage of such seemingly simple substances as water, air, etc., (1) into the form of inorganic salts, (2) into the forms of vegetable life, and (3) into those of animals. Point out how it explains thereby the interdependence of inorganic substances and vegetable and animal forms, and also the various natural processes of decay and dissolution.

2. Illustrate the mutability of material substances by the examples of carbon and silicic acid.

3. Copy, or write originally, a description of some place or event, pointing out therein ten examples of discrete quantity and ten of continuous.

4. Outline and illustrate the three methods of exact measurement described by Jevons in his "Principles of Science," pp. 282–299.

5. Describe clearly seven different kinds of standard unit as discussed by Jevons ("Prins. of Science," chap. 14), and show how derived units are obtained from one or more of these.

6. Make a careful abstract of Descartes' ideas as to matter as an underlying or original substance. (Cf. "Method," Pt. V, and "Prins. of Philosophy," Pt. II, or some good history of philosophy.) Give his theory as to how that substance came to assume the forms of our present world.

CHAPTER VII

ENERGY—DYNAMISM

Inquiry into Changes Leads to the Thought of Energy.—We have seen that scientific inquiry has occupied itself from the beginning with the phenomena of change. To ascertain the order and causes of the movements and transformations that go on in nature is the main objective of science. Indeed, the natural laws which it frames are properly but statements of that order and its conditions. Yet rarely, if ever, do these statements of sequence, however full and precise, completely cover the phenomena before the investigator. There remains for him probably always, in addition to the facts he has thus organized into a scientific system, a residuum of impression or conviction which is at once impressive and baffling; and which does not find expression in any of his laws, because it is too vague for clear statement. It is the conception of *energy* or *force* [1] or *power*—the working or efficient agent in the changes he observes. It is not a full account to say that the earth tends to move toward the sun inversely with the square of the distance. There is some

[1] The physicist's technical distinction between force and energy does not seem required for the purposes of this chapter. It is therefore ignored for the sake of simplicity.

agency which *produces* this result, though what that is we cannot tell at present.

Is Energy Actual?—This conception, which men in practical life generally take for granted, has been impeached by Hume in a notable criticism. He characterizes it as an illegitimate idea on the ground that it is not supported by any adequate "impression," or immediate experience. He shows first quite convincingly that we never actually come upon any power at work in changes that are external to us; that is, "any quality which binds the effect to the cause, and renders the one an infallible consequence of the other. We only find that the one does actually in fact follow the other. The impulse of one billiard ball is attended with motion in the second. This is the whole that appears to the *outward* senses." [2]

Nor will Hume allow that we have any inner experience of power, either in the movement of our bodies or the exercise of our minds. "The power or energy," he says, "by which this is effected, like that in other natural events, is unknown and inconceivable." In this, however, he seems clearly in error. He admits that all our movements are accompanied with a feeling of effort; but denies that this justifies the notion of power, or in any way warrants us in transferring the object of that feeling to situations beyond our immediate consciousness. "This sentiment of an endeavor to overcome resistance," he says, "has no known connection with any event: What follows it we know by experience; but

[2] "Enquiry," Sec. VII, Pt. 1.

could not know it a *priori.*" [3] Very true, but since this sentiment is always present in changes initiated by us through the medium of our bodies, why may we not conclude *a postiori* that there is some working agency (power, or energy) in our bodies either furthering or opposing our wishes? Hume's agnostic contention at this point is evidently the consequence of his expulsion of logical construction from the field of knowledge and his rigorous limitation of the latter to immediate experience.[4] The great part which discussion of the energies of nature plays today in the literature of science, both pure and applied, is evidence enough that Hume's extreme criticism has fallen to the ground. The fact seems to be that for most trained investigators, as well as for men in general, the straining of which we are conscious in our own organisms when in action is accounted sufficient ground for the posit of an active somewhat within us, a somewhat which is transferred to similar situations external to us, and used as the natural cue for their interpretation. The analogy between a human arm, for example, in the act of pulling a rope, and a toiling horse or a tugging steam-engine doing the same sort of thing, is too great to be ignored. If there is a mysterious factor within ourselves inseparably connected with the production of results, it does not appear why it should not be present in other objects which act similarly. That factor we call

[3] He adds significantly, "It must, however, be confessed that the animal nisus which we experience, though it can afford no accurate precise idea of power, enters very much into that vulgar, inaccurate idea which is formed of it."

[4] Cf. p. 53 f., *supra.*

force, energy, power, at times will. Criticism finds it easy to find defects in any *description* of this efficient agency, but quite unable to resolve it into anything simpler or more familiar than itself. It is evidently an object of immediate experience, a brute fact, albeit far from distinct.

Energy the Efficient Factor for Science.—Returning from the philosopher's criticism of energy to the scientist's practical dealings with it, it is to be noted that the latter accepts it on the ground of what it does or can do. "We find," says Professor Watson,[5] "bodies are capable of doing work . . .; this capacity for doing work is called energy." Thus coal possesses energy, because under proper conditions it is capable of heating buildings, drawing loads, and running factories. A noticeable term in the definition is the word "capacity." Energy is not merely a body's actual work doing, but its *capacity* for doing work. The energy of a storage battery is represented, not simply by the work it is doing at any given moment in propelling a car through the streets, but includes also the amount of such propulsion which it can effect if kept continuously at work until exhausted.

Energy of Action and Energy of Position.—Upon this idea is based one of the physicist's prime distinctions, the distinction between *kinetic* (moving) energy—that is, actual present activity—and *potential* energy, or *power to act* at the stimulus of suitable conditions. The waters in the reservoir of a power plant may be very still on a quiet day. Their kinetic

[5] "A Text-Book of Physics," p. 85.

energy is then slight; yet their potential energy, due to their elevation above the tail race of the power house, may be great, and perhaps vast. They *can* do a large amount of work. Now, this capacity, or potency, is plainly due to their position; to do that work actually they must leave that elevation and descend upon the power-wheels below. Therewith their advantage of position is lost; that is, in gaining actual present efficiency (kinetic energy), they have lost potential energy. On the other hand, if the waters were pumped back into the reservoir, the kinetic energy used up, or kinetically lost in the process, would be made good—friction aside—by the potential energy gained. The like is true in all cases of work doing, as in that of the uncoiling and recoiling of a spring, the expansion and compression of a gas, and so forth.

The Conservation of Energy.—From such facts the physicist concludes that in any closed dynamic system the total amount of energy will remain constant, the potential energy lost being balanced by the kinetic energy developed, and vice versa. A frictionless pendulum oscillating in a vacuum would, under the action of gravitation, be such a closed dynamic system. On its downward course it would develop kinetic energy, but at the cost of a precise equivalent of potential energy. On its upward course in overcoming gravitation and gaining an elevation equal to that with which it started, it would do work and loose kinetic energy; but this would be fully stored up and preserved in the form of the potential energy which it thereby acquired.

Such a system, if free from all interference—that is, if really closed—would keep moving forever. We know, of course, that no pendulum, however carefully made and adjusted, will swing forever. The reason is that it is not, and cannot be made, a completely closed system. There are always more or less in the way of interfering factors—friction, air-resistance, and so forth. Indeed, with one possible exception, we have reason to think there is no closed system in all the physical universe. That possible exception is the physical universe itself—*as a whole.* If it is the whole absolutely, all dynamic agencies being included *within* it, it would seem that there could not be any interference with it from without. Men of science have therefore generally concluded that in the universe as a whole the total amount of energy, kinetic and potential, is constant, a conclusion which is known as the principle of the *conservation of energy,* and which has been called the "keystone of modern science." [6]

There is a caution to be uttered at this point which is too often omitted. This "keystone" is largely metaphysical. It cannot be established experimentally, for no human senses and no instruments are able to discover empirically that absolutely no energy is ever lost in the changes of form which it undergoes. The experimental evidence simply *points* that way. Moreover, when we argue from the conception of the universe as a *whole,* that is, a complete and essentially limited dynamic unit, we are evidently dealing with a metaphysical idea, and one

[6] Watson, o. c., p. 87.

that is *assumed*. We do not know that there *is* any universe in this sense of a complete, self-contained, externally unaffected, physical unit.[7] Furthermore, even on the empirical side, the new phenomena of radio-activity seem to impeach the absoluteness of this "keystone" principle; for in them we seem to have cases of actual degeneration of matter, cases in which part of the material substance passes off in the form of energy, and ceases to be matter. If such is actually the case, the total amount of matter has been lessened and the total amount of energy increased, and neither matter nor energy is rigidly conserved.

Law of Constancy.—When taken, however, not as an eternal basal fact of the universe, but as a useful working principle, it is doubtful if any physicist considers that the core, or real purport, of the conservation of energy, or of its correlate the conservation of matter, still less of the two taken together, is affected by these new discoveries. It still remains true for him that the sum total of fundamental existence, *matter and energy*, and whatever other substances there may be, *taken together*, remains constant; for, whatever in radio-activity ceases to exist as matter continues to exist in the form of energy or electricity or something else. In other words, the new discoveries have greatly extended our conception of the mutability of existence and modified our ideas of the fixity of matter, but they have not destroyed our faith in the constancy of existence as regards

[7] Herbert Spencer based his cosmic theory on the denial of this conception. For him the universe was not a unit; it was infinite.

amount. This conviction, known as the *law of constancy,* is not based primarily on experimental evidence. Rather is it due to the inability of the human mind to conceive of the absolute beginning of substance or its absolute annihilation.

The Correlation of Energy—It is involved in the broad principle of conservation that energy is transformable. It is present in the world in various guises, such as mass movements, heat, magnetism, and so forth. These seem to be, not independent forces, as was once supposed, but modes of the one entity called energy. The evidence of this is that they can be converted one into another—an important truth which constitutes the principle called the *correlation of energy.* Energy, like matter, is wonderfully changeable; it is, indeed, a very chameleon as to type, having the capacity, and also the habit, of changing its form from potential to kinetic and back again, from linear to curved motions of various complexities, from molar—that is, perceptible mass movements—to those molecular shiftings which are imperceptible *as movements* but are often perceived in a confused way by the temperature sense as heat; from chemical activities to electrical, magnetic, and optical, and *vice versa.* Moreover, these transformations appear to take place under a system of precise equivalents, a given amount of heat, for example, being convertible into a definite, fixed quantity of electrical activity, and so forth.

Potency and Actuality.—In these dynamic metamorphoses the passage of kinetic into potential energy and, sooner or later, back again, is one especially hard to understand. How can we separate the notion of energy from that of action? Kinetic, or moving, energy is a term that presents a coherent idea; but what is "potential energy"? A kind of sleeping or latent energy seems to be implied, a power that can do things but is not actually doing them, an activity which is not at present active! How is that conceivable? How can we conceive of potential energy as real, that is, as activity? The answer seems to be that it is in a way similar to that used for the explanation of the metamorphoses of material things; it is by thinking of *imperceptible activities.* Changes of position of imperceptible components go far to account for the surprising changes that occur in matter. So imperceptible functions or activities may account for the fact that a body *can* do work when it is not doing it. We may think of the activity (kinetic energy) as present and sufficient for the work in question, but as occupied at present in other ways that we cannot see. Coal, for example, has a certain potential of heat and power. To think of that potential energy as a present existence, an actual activity now, we have only to conceive of the carbon and other molecules and atoms of the coal as busily engaged in processes which are too limited in range for us to perceive—a conception to which such phenomena as those of elasticity also point. They are occupied with intermolecular movements, and perhaps still more with interatomic movements; and from these secret processes, confined now to imperceptible ranges, comes all the furious perceptible energy later developed in the engine furnace; all, that is, except what is contributed by the atoms of oxygen from without. If we think of combustion as the riotous assault or wooing of the carbon atoms by the oxygen atoms, we may say that what is done in the process is merely to change the *direction* and *type* of the activity of the two kinds of atoms, not to awaken either of them out of sleep.

A simpler illustration is perhaps to be found in the case of a coiled spring, as in a clock. When the spring is released, we are not required to think that the molecules of the metal suddenly awake and act, still less that some new agency independent of them leaps into the field. All the energy which the released spring displays can be accounted for by the simple hypothesis, that before the release the molecules were swinging in symmetrical curves under the influences of two tendencies or dispositions—one to assume the open or uncoiled position with its greater freedom of molecular movement, the other (cohesion) to keep within touch of each other. The moment one end of the spring is released, the former tendency is no longer balanced by the latter, and movement of the spring as a whole—of all the molecules under the common tendency—is the consequence. It may well be that the potency of the waters in a power reservoir is to be similarly explained.

Thus actuality, to use Aristotle's term, (the kinetic type) seems to stand for energy manifested at long range, and in unbalanced, non-harmonic ways. In human beings we should call such courses intemperate, headlong, and passionate. Potency, on the other hand, stands for balanced, symmetrical, and in a sense self-controlled processes.

Diffusiveness of Free Energy.—No dynamic principle has, perhaps, greater practical bearings and more far-reaching metaphysical implications than that of the diffusiveness of free energy. On it is based the physicist's distinction between *available* and *unavailable* energy. Though energy is always capable of work, it will not always do it, by any means. It is not always available, the proper conditions not being producible. On a hot summer day there is a vast amount of energy present in the steam that hangs over the ocean and makes life a burden in the coast cities; but there appears to be no way of making it work. It is too generally diffused. Energy is available for working purposes only when it is concentrated and, relatively to the environment, intense. It is not the mere fact of gaseous (steam) pressure in the cylinder of a locomotive that makes it a powerful worker, for there is gaseous pressure all about the engine, without as within, below as well as above. It is the fact that the steam pressure within is so greatly in excess of the air pressure without. A steam pressure of fifteen pounds to the square inch would leave the engine as completely a "dead" locomotive as though there were neither steam nor fire within it; for fifteen pounds is the pressure of the outer air.[8] Evidently, then, one of the first problems of applied mechanics is to secure controllable *concentrations* of energy.

[8] In condensing engines greater availability and efficiency are secured by removing the antagonistic pressure of the air through the use of a vacuum.

Opposing this effort of the physicist and the inventor is the tendency of free[9] energy toward a state of diffusion, like that of heat in atmospheric vapors. In this way it is likely to be lost as regards availability. All active mechanical contrivances lose available energy through friction. Part of the force used by them is diffused thereby in the form of heat in the bearing parts. All heat engines, too, loose available energy through radiation, the heat passing into objects where it does no work, and generally cannot be reclaimed for working purposes. Now, nature is full of active mechanisms—seas, rivers, winds, moving creatures, etc.—and in all such cases, also, energy is continually running down into diffused and irreclaimable heat. Indeed, the great power source of the solar system, the vast sun itself, is unceasingly losing great stores of available energy through radiation.

As the physicist views this age-long process of "degradation" of energy, he draws two conclusions: (1) There is a time coming when no energy will any longer be available for work. It will all be diffused to a common level or pitch, and nothing whatever will go on. The universe will be a uniformly warm (or cool) mass, henceforth forever motionless and inert. This is not a cheerful prospect to one who looks upon creation with eyes of friendly interest. (2) "Since the quantity of unavailable energy is continually increasing, there must have been a

[9] This word is added here, because, if as the dynamists hold matter is made up of energy, then one form of it, what may be called *organized* or *fixed* energy, shows little, if any, of this tendency.

time when none of the energy of the universe was unavailable, and before which no phenomenon such as we are acquainted with can have occurred, for every such phenomenon necessarily involves a degradation of energy." [10]

This last conclusion bids us pause; for, if nothing went on in that prior time, how did the present (age-long) physical process begin? We known nothing of physical change without antecedent changes as its cause. We seem here to have an antinomy, or conflict of laws; for a corollary of the law of the conservation of energy calls on us to ignore the law of causation. It is evident that in such statements the physicist has crossed the border into metaphysics. As we have seen, his assumption underlying these conclusions is the metaphysical one that the physical universe is an absolute unit, a complete and closed dynamic system.[11] From the second conclusion to which it leads him, this seems to be a very questionable assumption. Other metaphysical conceptions are possible, some one of which may work better. We may, for example, think quite as properly that the physical universe is in some sort of working touch with a higher non-physical universe;[12] or we may regard it as merely the abstraction which our limited powers of knowledge make from a totality of existence

[10] W. Watson, "A Text-Book of Physics," p. 88.

[11] Cf. Whetham ("Recent Developments in Physical Science," p.5), "This final sleep of the universe depends on the assumptions that the universe is an isolated system, finite in extent, and that no process of molecular concentration of energy, such as was imagined by Maxwell, is going on anywhere throughout the depths of time and space."

[12] This is substantially the theistic conception.

much of which is non-physical and as such either quite or mostly unknown to us. If either of those conceptions is true, there must be possibilities in the future course of the world which no study of physical facts will reveal.

Vagueness of the Term Energy.—When we ask what this ever-present agency, called energy, is in itself, we put a question which cannot be answered. We do not know, just as we do not know what matter is "in itself," that is, what its fundamental functions and relations are. But it may be useful to inquire into the direction in which we may hope for an answer in future.

Energy Not a Mere Mode of Motion.—One thing may be affirmed confidently: energy is not *merely* a mode of motion. For the older atomism energy was simply motion, and motion in the simple sense of change of place, its different forms being due entirely to the complexity of the situations in which the moving particles often became involved. The formula—almost the sacred motto—of this hypothesis was, "Force is but a mode of motion," the change of place involved in the motion being thought of as more often molecular than molar. Now, motion is indeed the usual accompaniment or manifestation of energy; but it appears to be only the manifestation. No statement of motion pure and simple covers the idea of energy, which is instinctively conceived as the *moving agency*, not the phenomenon of moving. Energy, as we have seen, is "*capacity* for doing work." To describe the mover as an inert (that is, inactive or dead) particle is a contradiction in terms, for even to communicate or transfer motion is a kind of activity.[13] On the other hand, when the word "mere," with its dogmatic negation, is omitted, it appears to be, so far as it goes, a very true account of such forces as heat and light to call them modes of motion.

Other Theories as to Energy.—The logical possibilities as to the nature of energy seem to be three:

(1) It may be a *world-wide existence as universal and substantial as matter*, yet quite distinct from matter. From this dualistic [14] standpoint, formerly the favorite one with those who gave it due recognition, energy is the Protean formative agency of the universe, and matter is the pawn with which it plays, the brick with which it builds, the clay which it molds. We have seen that man at a certain stage in development is apt to attribute natural processes to special divinities whose whole nature consists in maintaining those processes. We have only to conceive of such divinities as but different forms or modes of one incessantly active divinity to have a close mythological analogy to this dualistic view.[15]

[13] This fact was overlooked by the old materialistic atomism, which believed that the world could be resolved into a complex system of moving but powerless units. It saw no problem in impact and elasticity.

[14] So called because matter and energy have generally been considered to make up the physical universe.

[15] The first to put this conception into outspoken philosophic form appears to have been Empedocles, who posited "Love" and "Hate" (attraction and repulsion) as the fundamental agencies of the world. This view should not be confounded with the theistic dualism referred to in the last chapter. In the latter the cosmic active agent is a person, not a blind force.

In its older form of a universal agency seated at once everywhere and nowhere, it was a vague conception belonging to elementary rather than to advanced science. It sufficed for such simpler generalizations as the statement that heat expands metals; but it gave no adequate analytical insight into natural situations, such as we gain, for example, when we say the molecules of a metal in that heightened state of activity which we call heat require more room, and *by that activity* secure it. In its present-day form, however, it is not open to this objection, for its seat now is placed in the units of matter, which are regarded as its centers of agency and vehicles of movement.

(2) Another possible view is that already referred to in the discussion of potency. It regards energy as a pure abstraction, a *mere general term for the various types of matter's activities.* From this point of view matter alone is substance, and forces and all energetic phenomena are merely the functions of matter—ways it has of acting. These ways differ greatly with circumstances. Ordinarily the molecules of water draw nearer together with the lowering of the temperature, but below about 39F. they do just the contrary, drawing more and more apart until at 32F. they spring into fixed geometrical groups, so forming crystals of ice. When the activities of matter are greatly alike on a wide scale we dignify them with the name of "forces." Thus the type of activity that seems to be most characteristic of molecules we call heat, that most characteristic of atoms we call chemical affinity, and that of the

thousand-fold smaller constituents of the atom we call electricity.

In support of this view it may be urged that our analysis[16] has shown the distinctive properties of matter—extension, weight, and inertia—to be largely, if not wholly, dynamic. Moreover, the other manifold, but perhaps not universal, properties of material things—elasticity, heat, chemical affinity, magnetism, etc.—appear to be dynamic likewise. Indeed, there is no property of matter, with the possible partial exception of extension, that is not an energetic one. The argument, then, is a fair one, that in using the terms matter and energy we are referring to mere aspects of one entity. Matter is known to us only by what it does, and energy is never found apart from matter. When thinking of it as a *substance*, that is, the possessor of properties and modes (forms of existence), we call it *matter;* when thinking of what it does, its *functions*, we commonly call these *forces*, or energy, whereas we should recognize them as mere activities of the substance matter. To invoke another substance to account for these functions seems to violate the law of parsimony by the reification of an abstraction. Thus, when the coal in the railroad car resists the efforts of the locomotive to move it—that is, manifests inertia—we attribute that to the coal itself. An activity of matter is all that is involved in that resistance. When later in the furnace fierce heat and vast masses of gas and vapor come from the coal, by what necessity is it that we declare the coal (and

[16] Cf. p. 87 f, *supra*.

oxygen) to be no longer the agent, but an additional existence called energy to have appeared on the scene and to have assumed the major role? The truth seems to be that when the molecules of coal resist the interference of the locomotive (that is, show inertia); when they oppose invasion of the space needed for their activities, as in thwarting the inrush of another car (show impenetrability); and when in combustion they throw off their former alliances with their fellows and join riotously with new mates (oxygen atoms), so displaying the activities of chemical affinity and heat, they are in all these cases alike *acting on their own account,* and are not the mere vehicles of some second and separate agent.

To such arguments the physical dualist responds by pointing out that the credentials of energy as a substance—a permanent existence in itself, and not the mere manifestation of something else—are virtually the same as those of matter. Is matter substantial because it is *transferable?* [17] Energy is equally transferable. Indeed, it is the real cosmic Mercury, flitting incessantly through the universe. Is matter a substance because it is mutable—capable of surprising changes of form? Energy is equally so; witness the transformation of invisible atmospheric heat into the lightning's blinding flash. The correlation of forces parallels the mutability of matter. Is matter *indestructible,* its total mass remaining constant? The like is true of energy, the conservation of energy standing on as good evidential grounds as

[17] Cf. p. 90, *supra.*

the conservation of matter. What reason is there then, it is demanded, why matter should be accredited as a substance, and energy be denied that rank? This is certainly a very pertinent question, yet it is perhaps not unanswerable.

It does not follow that if equal claims as to substantial rank can be established for the two entities separately, therefore both are to be accredited as substances *together*. On the contrary, when *either* matter *or* energy is admitted to be substance, the question of the substantiality of the other takes on a new aspect. "Theoretical existences are not to be multiplied without necessity," declares the law of parsimony. Now, given either one of the above as an admitted theoretical existence (substance), the question arises: Do we need to posit another? May not the phenomena represented by the other term be sufficiently accounted for as special activities or modes of the substance already recognized? The answer certainly seems to be that they may be so accounted for, and that consequently under the law of parsimony the other claimant is to be excluded from substantial rank.

But why, it may be asked, may not energy rather than matter, be the real substance? It certainly is conceivable that it may be; which brings us to the third view.

(3) We may think of energy as the true fundamental substance of the world, and matter as one of its modes, its more highly organized form. This is the conception embodied in the electronic theory of matter, or at least in one form of it. According to

that conception fundamental existence is essentially active—a heaving ocean of being—but it is *not* active *matter*; it is that more subtile, weightless agency which we call *electricity*. This, which is the real agent in all that goes on in the physical world, the root of all natural forces, exists in the form of more or less discrete and extremely active units (electrons), which are a thousand fold smaller than the hydrogen atom; units which more than make up for their lack of weight by the strong attractions and repulsions which characterize them. It is when a swarm of these units are organized into a permanent dynamic system that the material atom comes into existence, and manifests that weakened form of attraction which we call gravitation. These material atoms the theory recognizes as distinct and largely fixed types of being, but the static, inert aspect which they often wear is declared to be external only and altogether superficial. They are really, like the solar system, organized units of internal movement, and so are as truly and essentially energetic as the electrons which constitute them.

It will be seen that this third view agrees with the second in positing but one fundamental substance, but differs in regarding energy and not matter as that one substance. In this reversal of the perspective, it has the support of the remarkable newly discovered phenomena of radio-activity. The radium atom does seem to be constituted of components vastly smaller than itself, though whether these are to be regarded as electrons (dynamic substantial units pure and simple) or corpuscles (electrically charged bits of ether or what-not) is disputed. On either of these latter views, however, it seems impossible to think of matter as the fundamental substance. That which is made up of components is of course, not fundamental; it is rather a stage of existence—possibly the advanced and most important stage, possibly also merely an intermediate stage.

To sum up, it appears (1) that we may think of energy as a substance—a permanent, self-assertive, indestructible existence with constant properties—and think of it as such in connection with matter which is recognized at the same time as equally a substance. This view, however, seems to encounter the frown of the law of parsimony.

(2) We may think of it as merely a general term for the activities of matter—matter's way of behaving. The phenomena of radio-activity seem to make this inadequate, unless the behavior of electricity, and perhaps of the ether, is also taken into account.

(3) Finally we may think of it as itself the one fundamental (physical) existence, manifold in its forms, ceaselessly active in its nature, but capable of organization into sustained systems, or fixed types of activity, (atoms and molecules of matter) in which the movements take place mostly within the system and consequently do not affect our senses as free energy does.

This last view is philosophic rather than scientific; for in physics it is found more convenient to apply the term energy to the *activities* of an agent than to the agent itself—essentially the second view above.

It is quite possible, however, and probably common, to combine the second and third views by suitable modifications. One may lean to the electronic hypothesis, and regard matter as an organized form of electricity, and yet find it most useful to regard energy as an abstraction, a name for the activities of whatever is substantial, whether matter, electricity, or ether.

Electricity.—These latter views, together with the radiational phenomena of the vacuum tubes, radium, etc., have given electricity quite a new standing in scientific thought. It was formerly ranked with heat as a dynamic *manifestation* merely—a mode of motion. At present, whether identified with energy or not, it is generally considered to be a substance, a substance which, as we have seen, differs from matter in the far greater minuteness of its fundamental units, and in the fact that it bears a double, not a single, sign; that is, its units show *repulsions* as well as *attractions* for other electric units, whereas matter *as such* shows only (weak) attraction for other matter. On the other hand, matter's attractions are unaffected by the presence of intervening objects, while electricity's are not. In the electronic theory electricity is not fundamentally a different substance from matter but simply the elementary or atomic form of matter; and that whether it is identified with energy or not. The more conservative physicists, however, are inclined to regard it as a substance distinct from matter.

Ether.—Repeated reference has been made to a theoretical existence or substance called *ether*. The ether owes its standing in science primarily to the needs of optics. Since light is a wave movement, a medium in which the waves may travel is demanded; and no medium known through the senses is adequate. Of late this theoretical medium has been called for also by other branches of physics for bridging chasms between the facts. Thus, wireless telegraphy is supposed to utilize pulsations in the ether, and lines of strain in the ether have been invoked to explain a magnet's characteristic attractions and repulsions. Electrical theory, too, is disposed to call it in to furnish mass to the electrons or charged corpuscles which make up the atoms. These electrons are said to push or drag it along. The more thoroughgoing electronists consider it as essentially one with electricity, the electrons being but centers of influence or points of strain within it. Hitherto it has generally been thought of as quasi-solid, since nothing else seemed capable of transmitting vibrations at the speed of light. Yet this is a most difficult conception, for the planets swing through it at tremendous velocities, and apparently quite without friction. At present the solid conception is undergoing challenge, and the thought is broached that in the ether as in the atom the sensitive extension may be due, not to brute, static spread-outness, but to a high degree of activity of exceedingly fine units. This conception seems to point toward the identification of electricity and the ether just referred to, and to fall in with the idea that ether is simply substance at the lowest degree of organization. More *conservative thought*, however, prefers, as in the case of electricity, to regard ether as a distinct substance by itself, one of the four ultimate irreducible factors of the physical world, matter, energy, and electricity being the others. For *the radical school* there is but one fundamental substance, electricity, matter and ether being its modes; and it is a matter of verbal convenience whether energy shall be identified with electricity, or regarded as its behavior in all its various forms.

Seat of Efficiency.—One question regarding energy remains: Where does this work accomplishing agency reside? What is its *seat*—that is, the place where it shows itself and responds to stimulus, where it may be found, and perhaps be harnessed to human tasks? By the common consent of present-day investigators, its seat is *in* matter, not outside of it. Energy, whether we regard it as substance or a form of activity, is an agency internal, not external, to material things. The two are not related as is the water in the mill-race to the overshot wheel which it turns, but rather as the electric current in a power wire seems to be related to the lamp which it causes to glow. In the inorganic world it is in the molecules, atoms, and electrons that energy is to be found, abiding there either as potent occupant or as very essence. As a consequence for the physics of to-day these infinitesimal units are centers or systems of marvelous potencies, indeed the great power-houses of the universe. In living things additional seats of energy are found in the cells of the organism, and of course in the organic individual as a whole. In a man, for example, action may be aroused by some stimulus applied to the cells of his body, such as food or the fumes of ammonia, or it may be called forth by a stimulus applied to him *as a man*, a blow or a cry for help, for example.

It is noticeable that in all these cases of known seats of energy and efficiency the active agents are organized units; that is, they are dynamic systems of *internal* movement which maintain their respective types because of the mutual relations and activities of their parts. On a large scale the solar system, in which the form of the whole remains substantially unchanged and persistent because the planetary movements are continuous and in closed curves which themselves determine the form, is an example of such an organized dynamic unit. It is significant that nowhere do we get energetic responses from bodies or elements known to be without organization. Mere unorganized masses, *as such*,—stones, sands, waters, etc.—appear to do nothing of themselves. They move only as they are moved; they are literally inert. When activity appears in them, as in the vaporizing of water, it is because of *something their molecular or atomic constituents are doing*, and these constituents are organized.

Individuals.—It is convenient to have a general term for all kinds of organized units or centers, and that term is supplied in the word *individual.* This word has hitherto had little definite meaning outside the domain of living things; but the new conceptions as to the structure of matter and the seat of energy are making it needful to-day in the inorganic realm, also.[18] A true individual, whether organic or physical (inanimate), is *any existence whatever that is organized into a persistent unity,* or permanent type, and which is consequently indivisible in the sense that when broken up the type is destroyed. Thus a molecule of water is as truly an individual (indivisible) as a dog or a horse, because it has a persistent type which is due to its organization—two parts of hydrogen wedded to one of oxygen—and because on subdivision, that is, into oxygen and hydrogen, *it ceases to be water.* Using this term to signify all such organized and unified centers of existence, we reach the conclusion that the individual is the most important and significant kind of existence, for it is the only kind that is known to do things; it is everywhere the working agent, the seat of energy and efficiency.

Exercises

1. Describe five distinct cases of the correlation of forces, each of them involving at least two transformations.

2. When a broadside is fired from one of the newer battleships, with, say, an energy sufficient to lift a dozen of the large ocean liners (Cf. "The Super-Dreadnaught" in Harper's W'kly, May 25, 1912), show where that energy was in all the long preceding months when the guns and powder were idle. Show how we can conceive of it as not sleeping but active (i. e. actual), and what were the more evidently active states that preceded the manufacture of the powder.

3. Give in detail five examples of the apparently irretrievable loss—that is, "degradation"—of available energy.

[18] In fact they bring a challenge to the very notion of any part of nature as truly inorganic, that is, unorganized. A world the fundamental active constituents of which are individuals would seem to possess necessarily some measure of organization everywhere.

4. Describe five cases of potential energy, and show in each how the seemingly latent force may be thought of as actually kinetic.

5. Give three examples of physical individuals, and show what likenesses they have to organic individuals, such as single plants and animals.

6. Give in your own words a detailed abstract of Hume's argument ("Enquiry Concern. Human Understand.," sec. 7) against the validity of the idea of power, making clear what his canon of a valid idea is, and how he maintains that this canon is not met in our experience either of outward objects or of our bodily movements nor yet in the workings of our minds.

7. Discuss critically the grounds of our belief that energy and matter—one or both—are indestructible.

CHAPTER VIII

MECHANISM

Professor Huxley in one of his popular lectures lauds the philosopher Descartes as a notable pioneer in the science of physiology. His strongest count in behalf of the noted Frenchman is that he saw that "the remotest parts of the universe" are "governed by mechanical laws," including "our own bodily frame," and "attempted for the first time to account for all natural phenomena as only a simple development of the laws of mechanics," [1] "with the effect of arriving. . . at that purely mechanical view of vital phenomena towards which modern physiology is striving." Descartes had said in his "Discourse on Method," "This motion which I have just explained [the circulation of the blood] is as much the necessary result of the structure of the parts which one can see in the heart, and of the heat which one may feel there with one's fingers, and of the nature of the blood, which may be experimentally ascertained, as is that of a clock of the force, the situation, and the figure of its weight and of its wheels;" and Huxley adds, "Thus according to Descartes the animal body is an automaton, which is competent to perform all

[1] Cf. "Method and Results," lec. 4. The last statement is quoted approvingly from Biot.

the animal functions in exactly the same way as a clock or any other piece of mechanism."

In this mechanism in the case of man the rational soul, according to Descartes, has "its principal seat in the brain," and takes "the place of the engineer" in the mechanisms made by man. This soul engineer does none of the work of the body machine, however, but, like an ordinary motorman, merely determines the time, direction, and degree of its movements. The character and causes of those bodily movements, such "as the digestion of food, the pulsation of the heart and the arteries, the nutrition and the growth of the limbs . . . the internal movements of the appetites and passions . . . these functions in the machine naturally proceed from the mere arrangement of its organs, neither more nor less than do the movements of a clock, or other automaton, from that of its weights and its wheels; so that, as far as these are concerned, it is not necessary to conceive any other vegetative or sensitive soul, nor any other principle of motion or of life, than the blood and the spirits agitated by the fire which burns continually in the heart, and which is no wise essentially different from all the fires which exist in inanimate bodies." [2]

Since Professor Huxley's essay was first published the scientific appreciation of the idea of mechanism, and scientific confidence in it, have waxed rather than waned. To the physical scientist to-day it is the master key to the universe. No doubt, like other master keys, it will not open every lock, but he is apt

[2] *Ibid.*, quoted from "Traite de l'Homme."

to think that no lock really opens without it. On the other hand, these views of men of science are unwelcome to many philosophers and most theologians. To them the conception of nature as a mechanism is at best a superficial abstraction, useful no doubt for certain practical ends, but misleading and even debasing, if taken as a true account of real existence. As a recent philosopher expresses it, "this way . . . lies confused thinking, nay, folly." [3] To call man a machine seems to such thinkers an impeachment of his dignity, a virtual denial of his personality and higher possibilities.

It is evidently important to ascertain just what the man of science means—or should mean—by declaring that all nature is mechanical. What is necessarily connoted by the term "mechanism" as applied to nature? If we reflect critically upon any machine of human construction, a locomotive or a steamship for example, searching for the distinctive idea embodied in it as a mechanism, we shall probably agree in finding it first of all in the conception of a more or less *unitary whole made up of interconnected parts,* a whole in which all the movements are determined and explainable by relations between the parts, not through some outside agency. In this governance from within through the action of one part upon another we seem to have the distinction between a machine and a mere tool. A spade goes into the soil because the laborer holding it drives it in; but a steamship does not move because any man or divinity pushes it on. The movement of a steam-

[3] Fawcett, "The Indiv. and Reality," p. 92.

ship are explainable purely by its structure as this is related to the two elements in which it moves (water and air); that is, by *factors* (structural parts and forces) *within itself.*

A further idea involved in the conception of mechanism is that the parts work together without any choice on their part of the ends served by the mechanism as a whole. It is not because rudder or screw or any other part of the ocean "liner" itself wishes and chooses to reach the transatlantic goal that it directs its course and the course of the steamer thereto. Nor yet do all the parts take counsel together, decide on that goal, and then work collectively toward it. In the ship's mechanism each part merely does what its nature under the circumstances leads it to do; and the outcome, whether of harbor reached or wreck met, is due to the way these parts are adjusted, on the one side, to one another and, on the other, to factors (winds, currents, etc.) which bear upon the complicated whole from without.

Now, it is the conviction of present-day natural science that these two ideas, or principles, hold good also in all natural processes. A human body, for example, does not go through its multitude of remarkable activities—digestion, circulation, respiration, nervous reactions, and so forth—because some intelligence, some spiritual being or animal soul, dwells within it and consciously keeps each organ doing its part. No, the saliva flows to meet the food taken into the mouth because it is the nature of the salivary glands to produce it under the stimulus of contact with food, and the ptyalin ferment in the saliva acts on the starchy elements in the food because it is its nature, wherever found, to convert starch into dextrin and maltose. That is, it is a chemical, not a personal, reaction on the part of the ptyalin. So with the activity of the stomach; it is not aroused to action because it wishes the incoming masticated food to be churned up with the gastric juice before passing it on to the intestines. Its activity is aroused by the mere contact of that food. Apparently, if it could be itself properly nourished and supported, it would act with equal efficiency if it were removed from the body and placed in a glass vessel. For like reasons the digested food is absorbed from the intestines, and carried on to the tissues. So with all the functions of the body; they go on for reasons that are essentially the same as those which control the workings of a steamship or an automobile. The remarkable results in the co-working of *all* the parts—the great voyages in the case of the ship and the throbbing, sensitive life in the case of the organism—are due apparently, not at all to the rational choice of the parts themselves, but *to the form of their combination* and their adjustment to each other.

This seems to be the substance of the idea of mechanism as applied to nature. It may be made somewhat clearer by analysis, for it involves more or less clearly five sub-principles, namely, adjustment, interaction, continuity, uniformity, and causation.

1. Adjustment.—A machine, or concrete mechanism, is a construction, or unitary whole, in which the parts are of such a character as to be capable of functions of service one to another in behalf of some established, or regularly effected, end. The parts of a printing press, for example, are not only located near each other—say, in the same room—but by their very position, shape, and composition are capable of leading to the production of printed sheets of paper. Not any casual jumble of steel levers, cogs and so forth, will print a newspaper; nor will the right *kind* of parts if they are not properly *placed.* The character of the parts in these respects of form, position, and so forth, *relative to each other*, is what is meant by their adjustment. In the case of a printing press the adjustment looking toward the printed result is, of course, designed. The question whether it is designed or not in the case of natural mechanisms leads into sharply disputed philosophic ground, entrance upon which may well be postponed a little. Certainly on applying to natural situations terms taken from ordinary industrial experience we should be on our guard against assuming resemblances which may not exist. It is sufficient at present to note that the principle of mechanism means that nature is a vast system of adjustments which, as a matter of fact, and by established, orderly processes, *do* produce results which, from the standpoint of our human experience, are to be expected from those processes, and hence are predictable.

2. **Interaction.**—Adjustment of parts would be a futile thing if the parts did not act, and act upon each other, when the adjustment was effected. What the railroad men call a "dead" locomotive is a case in point. The parts, including water and fuel, may

be all present and in position, but there being no action of one upon another, there is no movement on the part of the engine.[4] When nature is described as a mechanism, it is meant that it is a "live," not a "dead" machine; the parts always do act when the proper adjustments are effected.

In all machines properly so called, that is, machines that effect results, the *essential parts* are active; whatever is not so is dead weight, and not essential. It is only through a figure of speech, which easily runs into false abstraction, or the fallacy of simplification, that one comes to regard the parts of a steam-engine, for example, as inert—mere passive tools of a force independent of them. Every molecule of the iron or carbon, if really an integral part of the engine, undergoes strain, and reacts to it, when the engine as a whole is working. Not a thrust or a pull is made but the molecular constituents of the machine have a part in it. The molecules of steam differ from those of the inclosing iron only in being active in a non-harmonic way and perhaps an acuter degree. This difference in type of activity as between the solid and fluid parts seems to be greater in man-made than in natural mechanisms.

3. **Continuity.**—In a machine the parts act upon one another and produce results only when they are in contact, directly or indirectly. They must bear

[4] This is really a case of defective adjustment; for the adjustment in a locomotive has not been effected completely until the fuel is burning with the required vigor. A "dead" machine is always of this imperfect character, for whenever the adjustment is complete, in either man-made or natural mechanisms, the parts act.

upon one another in some way, either by immediate pressure or impact, or through one or more connecting links. From end to end of the machine there must be no real gap in the dynamic continuity, or it will not work; that is, there is no such thing in a machine as action at a distance without intervening medium. Now, men of science are convinced that the like is true of natural processes. "Nature does not work by leaps"[5] either in space or time. However seemingly solitary the phenomenon may be, science holds that inquiry will in time always show that it was the result of interacting agencies adequate to its effectuation which were all connected with it in a causal series without break. If a light flashes across the "void" spaces of the heavens, it is not because a luminous body millions of miles distant can directly affect our eyes, but because the pulsations it starts in the ether produce other pulsations beyond themselves and these others still in unimaginable swiftness, until the last of the series smite the retinas of our eyes. The principle is equally valid in the matter of time. If the sound of a distant impact reaches us at an appreciable interval after sight has acquainted us with the event, it is not because there is any interval in which nothing leading to the sound effect is going on, but simply because the processes (air pulsations) which lead to the sensation of sound move slower than those which lead to sight, and during the interval have not yet reached our ears. In both cases the single items of the processes are connected with one another in both time and space

[5] *"Natura non agit per saltum."*

as intimately as the links of a chain or the strings of a net.

4. **Uniformity.**—It is an integral part of our conception of a mechanism that it should be *uniform* in its workings. We expect a machine *as such* to do the same thing under the same circumstances. When it fails to do so, we count it a defective machine; something is wrong with it, probably with its adjustment. On the other hand, we estimate its excellence largely by this very test—whether it turns out uniform results. It is quite natural that we should do so; for, if the action of its several parts is simply the expression of their nature, their normal form of activity under the given conditions, they should evidently, since the permanent mechanism, or whole, keeps the conditions unchanged, always do the same thing. Natural processes, likewise, have come to be regarded by the man of science with precisely this expectation. With like conditions, he affirms, like results will always issue. At the dawn of science this expectation was apparently but a hesitating postulate, adopted because it was needed. Uniformity was an initial assumption full of hazard. But age-long observation and the experimental research of a multitude of inquirers have so confirmed the original assumption that it is now regarded with all the confidence of an experimentally discovered principle.

It is involved in the conception of the uniformity of nature, at least in its modern empirical form, that natural agencies are *determinate*; that is, they have, under given conditions, *a definite, unchanging mode of behavior*. Whether this determination, and consequently the principle of uniformity itself, are absolute, or only so in the main, is a vexed question of philosophy which will be considered in the next chapter. Science as such is not concerned with this question. It *assumes* that its subject-matter is determined so far as its field goes, that is, so far as empirically verifiable results are involved. Its assumption thus far has worked, and, whatever the absolute situation, is likely to work indefinitely long in the future.

5. **Causation.**—Not only is there in a mechanism a certain definite, unchanging type of activity characteristic of each part; not only, moreover, are the results effected by the mechanism due to the interaction of the parts, but there is also a certain fixed *type of* this *interaction.* There is an established *order*, or *sequence* of activities. In a steam engine, for example, the regular, indispensable order is, in outline,—combustion, superheated water, high pressure vaporization, admission of the steam in rapid succession to first one side of the piston and then the other, and so forth. It is in this order of internal interaction that the steam engine works, and in no other order will it produce its characteristic results of strain and movement. It is idle to try to start the piston before the steam has been generated, and it is useless to open the throttle before the water has reached the right temperature. This familiar fact may be generalized under the statement that results will not appear until their proper antecedents are present and free to act.

This is precisely the state of things which men of science see in the natural world, and which they call the *principle of causation.* Everywhere in nature events occur in certain established orders of sequence. This they have found to be so universally true that scientists have become fully convinced that, apart from its proper antecedents, or causes, no event whatever takes place. In a sense the established antecedent is necessary, or indispensable, to the effect, though why it is so we often find it hard even to surmise. Causation is thus for the scientist simply one aspect of the world-wide mechanism, the aspect of invariable and apparently indispensable sequence.

It would perhaps not be needful to say more on this point, were it not that the discussions of the subject have been much confused by the use of the word *cause in the popular sense,* which is also the older sense. The notion of causation, as common life and the ethical and juridical ideas of responsibility have induced it in us, roots in that of *personal agency,* which always includes the element of *power* or energy. For men in ordinary life,—indeed, for all men in a multitude of practical situations—to inquire into the cause of an event is to ask what person or power brought it to pass. This seems to be the natural signification in the case of a crime or an explosion. As most men do not investigate deeply, a plausible answer to this question is generally sufficient. But science, with its spirit of rigor, has found that a satisfactory answer to that question is beyond its reach. Both person and power are terms shrouded in obscurity. The law may ascertain the man who "committed" a crime, and may punish him for it; but science is not satisfied that "he" was the cause of it in the sense implied in common thought, that is, the true originator, or source, of the event. It finds the man himself a plexus of forces, and among these are many impulses handed down from past generations or inbred by society. Where then do the impulses which resulted in the crime head? It does not know. Such inquiries lead out beyond its present pale.

Science has therefore broken with the ordinary notion of cause, retraced its steps, and decided to confine its inquiries to the ascertainable. It is content to ask for the invariable and apparently indispensable antecedent of the event, being convinced that the knowledge of such antecedent will give ability to predict, and often to control, the event, and not improbably be of more practical value than a knowledge of the absolute source of the factors involved in it. This indispensable antecedent it calls by the old word "cause," unhappily at the cost of no little ambiguity. Causes are, indeed, the great objectives of science; but it is not causes in the sense of original *sources* of phenomena, but causes in the sense of *indispensable cogs in the mechanism* by means of which phenomena appear. Thus, the scientific cause of an explosion is the immediately pre-existent situation, such as the presence of a highly organized compound or mixture in unstable equilibrium conjoined with an interacting agent, perhaps trivial in itself, which destroys the equilibrium. Science calls such an antecedent situation the cause because it is indispensable to the effect. Common thought, on the other hand, if penetrating enough, would locate the cause in certain forces believed to reside *in* the compound.

There is a disposition on the part of some writers to condemn the popular and older notion of cause as an illegitimate one, but without sufficient reason. It is probably true that at present it is not a scientific concept; but there appears to be nothing illegitimate about it. It answers to a natural human interest, the desire to penetrate to the sources of things. Indeed, it seems to be a phase of the *contemplative* interest in mechanism, a craving to follow the perpetually changing stream of things back to its origins; in other words, to witness the *whole* of the process. It is much truer to say that the two concepts of cause relate to different aspects of nature, the scientific to the more immediate and verifiable factors productive of change, the popular—which might also be called the philosophic—concept to the more ultimate factors. The one emphasizes the sequential aspect of nature, the other the dynamic.

To summarize the results of our analysis of the idea of mechanism as a principle of science it appears that it stands for the *conception that nature is an established, working, comprehensible order*, something organized and regular, active and efficient, something which can be understood through the analogies of human activities and human devices. It seems to be true, however, that to individual scientists, and still more to certain philosophers, the term mechanism has special metaphysical connotations.

Mechanism and Materialism.—One of the most common of these further meanings is that of blind momentum, mass and motion each of the simplest kind, as the one agency of control in the universe. This notion generally involves the idea that the parts which constitute the mechanism of nature are dead, inactive pawns pushed about either by the impact of other such pawns or by unknown and blind forces. This is essentially the older materialism, a kind of apotheosis of push. But this special, metaphysical conception of mechanism is by no means involved in the term. It is one very difficult, if not impossible, to apply to the phenomena of biology, or even to those of chemistry. Furthermore, the terms mechanism and machine are freely used in common speech for organizations in which the units, or parts, are active and even conscious. Thus, the phrases "mechanism of trade" and "mechanism of exchange" are common and natural; armies—those of Cromwell and Napoleon, for example—have been described as machines; and who has not heard of the political machine? It is the belief of the panpsychist school of philosophers that every molecule and atom—one of steel, for example—has a psychic or quasi-conscious side. Should it prove that they are right, it does not appear that a steam engine or a dynamo would be any the less a mechanism on that account. The cells of a living body have each their own life, with its birth, nutrition, decay, and death, and they may have, also, an elementary grade of consciousness; but neither of these higher characteristics prevents them from being integral parts of the body, which itself is evidently a mechanism, a kind of heat engine. The essential nature of a mechanism is not to be found in the idea that its parts are simple, inactive, and impotent, but in the fact that they are uniform in function and so adjusted to one another that their combined functionings produce regularly effected, and so predictable and controllable, results.

Fallacy of Simplification.—Having seen how many pitfalls beset the path of constructive thought, it will not surprise us to find one lying close even to the very helpful concept of mechanism. Many a radical mechanist has fallen into it. The *fallacy of simplification* consists in assuming that, when a natural mechanism has been traced out and described the phenomena characteristic of it have been *fully* set forth and accounted for. As a matter of fact, however true and valuable the mechanical description may be, it is after all an account of part of the facts, not of the whole of them.[6] To assume the contrary is to forget that a mechanical description is necessarily in general terms, and that the more

[6] Cf. the remark of Mach, "Purely mechanical phenomena do not exist . . . are abstractions, made, either intentionally or from necessity, for facilitating our comprehension of things. The science of mechanics does not comprise the foundations, no, nor even a part of the world, but only an aspect of it." "A person who knew the world only through the theatre, if brought behind the scenes and permitted to view the mechanism of the stage's action might possibly believe that the real world, also, was in need of a machine room, and that, if this were once thoroughly explored, we should know all. Similarly we, too, should beware lest the *intellectual* machinery employed in the representation of the world *on the stage of thought* be regarded as the basis of the real world." ("Science of Mechanics," chap. V, pt. 2.)

immediate and peculiar features of the object under inquiry are abstracted from and not included in it. A description in terms of adjustment, motion, number, order, and so forth, is the kind of description that will apply to multitudes of cases, and which therefore must omit what is distinctive of those cases taken singly. Especially does it fail to do justice to the data, its interest being in the relations, not in the elementary facts; and no complete account of a connected body of phenomena is given so long as the arrangement and actions of the parts are described, but the source and ground of the activities of those parts is left unrevealed. Thus, a biologist, confronted as he is with phenomena that are enormously complex, naturally gives his first attention to those features that are comparable with other natural processes—the mechanical features. These he finds at once comprehensible and surprisingly open to discovery and precise description. Encouraged by this important fact, he naturally looks forward to the time when such ascertainment of mechanical processes will be complete; and, if he is not on his guard, he is likely to forget that he is dealing with an abstracted, not an actual, situation, and to think and maintain that then, when the last computation has been made, he will have a complete account of the phenomena before him. But surely he will have nothing of the kind, however valuable and true his results. To catalogue all the groupings and movements of cells, and the external, or mechanical, conditions therefor, is not in the last analysis to tell *why* a cell does anything at all.

It may be objected that to raise such an ultimate question as that is unreasonable, since explanation has to do only with the inter-relationships of the fundamental data of experience, not with the origin and ground of the data. The *elements* of knowledge, the "brute facts" of experience, are not open to explanation; if they were, they would not be the fundamental data that they actually are. The reply is largely just; but it only re-enforces the point made in the raising of the question objected to, the point that no description of mechanism is ever a full account of the segment of existence with which it deals. To the mechanical interest the ultimate data are points of *departure* not disclosure—in a sense secondary matters. Furthermore, it is not true that, when mechanical explanation has done its best, there is never any further explanation to be given of the functioning of an organized bit of nature. We still have in all living forms the important factor of *value*; and it is quite possible that this factor may account for functionings of a cell, or even of a molecule, before which mechanical explanation is dumb.

Exercises

1. Describe in detail the process of digestion, and show its mechanical aspects.

2. Do the same with the circulatory system of any warm-blooded animal.

3. Point out all the essential characteristics of a mechanism referred to in Hough and Sedgwick's, "Human Mechanism," chaps. I and IV.

4. Make a careful summary of Huxley's essay on "Animal Automatism" (Cf. "Method and Results," essay V), pointing out all the considerations which warrant the description of a human body as a mechanism.

5. Summarize carefully Hume's account of what he holds to be the true conception of cause ("Enquiry," etc., sec. 7, pt. 2) in its two aspects, and contrast it critically with the main idea of cause that actuates detectives in their work, as, for example, in the investigation of the dynamiting of the Los Angeles newspaper office.

CHAPTER IX

LAW—VALUES

Hume in his famous essay on miracles relates the case of a man in Saragossa, Spain, seen by Cardinal de Retz, "who had served seven years as a door-keeper [in the cathedral], and was well known to everybody in town that had ever paid his devotions at that church. He had been seen for so long a time wanting a leg, but recovered that limb by the rubbing of holy oil upon the stump; and the cardinal assures us that he saw him with two legs. This miracle was vouched for by all the canons of the church, and the whole company in town were appealed to for a confirmation of the fact, whom the cardinal found by their zealous devotion to be thorough believers of the miracle." Hume notes that de Retz himself was "of an incredulous and libertine character," and so not prejudiced in favor of the event, which itself was also "of so *singular* a nature as would scarcely admit of a counterfeit, and witnesses very numerous, and all of them in a manner spectators of the fact," so that we seem to be presented with a remarkably well attested miracle. Nevertheless, Hume holds that the story is not to be believed. He cannot account for it, but as a miracle, it is necessarily a "violation of the laws of nature," and hence incredible. This is substantially the view of men of science to-day: a violation of natural law is not to be credited.

Now, what are these laws of nature which are to be trusted in preference even to unanimous testimony and to what *seems* the clear evidence of the senses? Obviously, for one thing, they are ideas[1] not facts, principles—mind-made bits of knowledge—not experiences, for they are never perceived by the senses. The vast majority of those who have lived upon the earth, however keen their vision and hearing and other senses, have never known them at all. Moreover, they are *empirical* principles; they are always the fruits of experience, generally of experience due to deliberate inquiry, and are neither ways of studying nature, nor necessary assumptions made at the outset.

This was as far as Hume was willing to go. For him the laws of nature were simply statements of the way that natural processes are, in our unbroken or total experience, actually found to take place. Just on this fact, namely, that they are drawn from and supported by the totality of our experience, he founded his well known argument against the miraculous. Miracles, being at best drawn from a part, and generally a very small part, of human experience, are not to be received in defiance of the totality of our experience as expressed in natural law. Now, Hume's conception of law is substantially that of science. It has discovered, as we have seen,[2] that natural agents, factors, and elements, at least so far as they are mechanical, are determinate; that

[1] Cf. p. 24, *supra*.

[2] Cf. p. 143, *supra*.

is, possess a characteristic, constant way of behaving. They can be relied upon to act in these ways (under proper conditions) both in the present and the future. Moreover, these ways are often the same, or indistinguishably similar, as regards a vast number of individuals, so that any one of these constitutes a type of the rest. When these typical determinations, or fixed forms of functioning, especially those which prevail on a wide scale,[3] are described succinctly, we have what science calls a law.[4]

The Reign of Law Accounted for.—For science, then, the word law stands for a statement of certain of nature's determinations, or fixed types of behavior; and the phrase, "reign of law," is merely a metaphorical term for the principle that the world is determinate in wholesale, typical ways.[5] It is common, however, to carry this subject from the field of science over into that of philosophy, and to seek a *reason* or ground for nature's determinations. As to this inquiry three leading views dispute the

[3] It would not be improper, however, to speak of the description of the established functioning of a *unique* individual as the law of its nature.

[4] Cf. A. L. Jones, "Logic," etc., p. 8, "A law in the field of science is a statement of the way in which things do invariably behave." This is better than F. T. Weil's formula, that "a law in science is a statement of how, under specific conditions, a thing invariably does and must act"; for in the latter definition the word "must" cannot be proved. It is philosophical perhaps, but not scientific.

[5] Cf. Wheetham, "The Recent Develop. of Phys. Science," p. 31: "Many brave things have been written, and many capital letters expended in describing the Reign of Law. The laws of nature, however, when the mode of their discovery is analyzed, are seen to be merely the most convenient way of stating the results of experience in a form suitable for future reference," etc.

pre-eminence. (1) The first is that of absolute determination, which may well be distinguished by the old Democritan term, *necessity*. Necessity, in this connection,[6] means movement impelled entirely from behind, so-called blind impulse, action regardless of consequences. It is the type of activity that seems to be present in all inorganic mass movements, from the tornado to the explosion in a rifle or the action of a poison. The motivation is, so to speak, entirely from behind; what is in front, that is, in view or to follow, has no influence. The agent acts in the given way "necessarily," because it knows no other way to act; in fact it knows nothing at all. The "necessity" of such mass movements probably impresses us most in the aspect of complete indifference to human interests which inorganic nature so often wears, as in shipwrecks, conflagrations, the earthquakes at San Francisco and Messina, and the volcanic eruption on the island of Martinique.

> "Streams will not curb their pride
> The just man not to entomb,
> Nor lightnings go aside,

[6] Like most philosophical terms the word necessity is equivocal. It often stands for a felt physical compulsion, force exerted more or less against the will of the one acted upon. As such Professor Huxley scouts it, holding that the idea is an intruder in physical science. To Hume it seems to have meant the logical or psychological pressure that obliges one to accept a conclusion involved in the premises. As such he argues at length and cogently against its admission into our knowledge of matters of fact. There is nothing necessary about these, he holds; they might quite as well, for all we can see, have been otherwise than what they are ("Enquiry concerning the Hum. Understand." Secs. IV and VII). The meaning discussed in the text is the one which has been most prominent in philosophy.

To give his virtues room;
Nor is that wind less rough that blows a good man's barge."

That this is an important aspect of existence is obvious; but is it the one and only true aspect, compared with which all differing aspects are but seeming? If, as is often the case, one answers this question in the affirmative, and assumes that necessity is the truest expression of the nature of things, then he will naturally account for the "reign of law" by saying that the determinations of things set forth in natural laws are eternal and absolute, and are to be accepted as brute facts that are neither explainable nor in need of explanation. He will hold that at bottom things always were what they are now. The only change has been in their combinations, and these come about solely through earlier movements of theirs which in turn were the necessary outcome of their fixed nature. What they do is done because they *must* do it, and nothing else is possible to them until external conditions change. Never will they do anything but what under identical conditions they have always done.

For the physicist this is no doubt the easiest explanation. It is a difficult one to apply, however, in the biological sciences; for the reason that living things, especially those capable of voluntary action, evidently act in view of results—things in front (in the future). A king-fisher pounces upon a minnow and a fox upon a rabbit, not because either of them is pushed on from behind, but because each is eager for the coveted food. So characteristic is this of organic nature that when we raise the question, why, regarding any action of the organism, whether the course of a statesman or the movements of an ant, or even the functionings of a specialized organ such as an eye or an ear, it is not generally to find out the mechanical antecedents of the event, but to learn what are the satisfactory results which justify that action and which in conscious activity, prompt it.

Moreover, not a few dissent from the doctrine of necessity, or utter determinism, on logical grounds. It is objected that the doctrine puts arbitrary limits upon the field of inquiry. Why *assume* that the elemental characteristics of existence had no genesis or history; and that complexity is eternal? It is a familiar fact that on the empirical plane all living things *grow* and *acquire* character; why not, also, things on the conceptual or molecular plane? Is it urged that it is because they are not living? But how do we know that? May they not be in a sense alive,[7] and may not their determinations be *acquired* characteristics, *habits* of activity formed in the slow lapse of ages? And if so, may not *some* parts[8] of existence be still indeterminate, and certain of the highest parts, the personal for example, even never become wholly determinate?

Necessity and Naturalism.—The doctrine of necessity is maintained mostly by adherents of the metaphysical doctrine of *naturalism.* This is the theory that whatever takes place in the world is due primarily and chiefly to the inherent nature of

[7] Cf. p. 165, *infra.*

[8] These might be relatively few and quantitatively small, and yet be dynamically of great importance.

the agents involved, not to any control external to them. Naturalism recognizes fully, of course, that the action of one substance or individual affects or conditions the action of other objects with which it is in some kind of contact, direct or mediate; but it denies, or at least refuses to admit the need of supposing, that any single intelligent agency, and especially any immaterial agency, is in full control of all the objects of the world. Whatever things *do*, it maintains, is owing to what they *are;* the event is always the resultant of the natural forces, physical and mental, that are in the objects concerned. Thus, according to naturalism, when a man goes insane we are not to attribute the untoward event to the will of God,[9] nor to the invasion of his body by a demon,[10] but are to look for explanation of it to the neural structure of the man himself as this has been affected and conditioned by the circumstances (physical, social, etc.) of his life. It is evident that naturalism in this sense—a confident reference of events to the *natures* of things—is very characteristic of men of science.

On the other hand, it appears to be a metaphysical motive, and not any scientific need, which leads some thinkers to carry naturalism to the extreme form of the doctrine of necessity. That all substances and all individuals act, under given conditions, according to their natures, rather than merely or chiefly under

[9] Cf. 1 Samuel 16:14, 15, 23; 18:10. The explanation of the absolute idealist seems to amount to much the same thing as the above, though of course in a much less naïve way.

[10] Cf. Luke 8:27–33.

the purposing agency of some higher power may be exceedingly probable; yet at the same time their activity may be in some directions—perhaps in many—far from blind and regardless of consequences. The flow of blood in an animal from a fatal cut seems to be a case of purely necessitated action; it moves regardless of consequences. On the other hand, the ordinary functions of the white corpuscles in the blood—the phagocytes—seem to be distinctly intelligent and purposive, albeit due no doubt to their nature. They seek and hunt down the harmful microbes in the blood stream much as cats exterminate mice. So naturalism may be true and the philosophic notion of necessity not true; that is, necessitated activity may be but one form or phase of natural activity, the form or phase which is especially characteristic of mass movements, or non-individual activities.

(2) A second view—also a heritage from antiquity—puts a somewhat similar [11] conception into dualistic form. It is the idea, usually associated with the name of Plato, that natural laws are *fixed factors of control in the world,* but are in a sense distinct and separate from the objects which they control. They are not gods, not being conscious or purposeful, but are *godlike,* since they are supreme, immaterial, and eternal. Plato felt, with the more serious men of his time and of the preceding Periclean epoch, that there must be somewhere a changeless basis to things; something must be eternal. Yet he could find that unchanging basis nowhere in what could be seen or

[11] *I. e.,* deterministic.

touched or heard. On the other hand, he noted that the *types* of the changing objects of nature—trees, animals, and so forth—appeared to be constant. He drew the conclusion that the unchanging eternal basis which he sought was an order of immaterial types which somehow controlled matter and fashioned it into their likeness. His view as to how this fashioning was effected was one not generally acceptable now to those who magnify the reign of law, being that of final instead of efficient causes; but the conception itself, that natural laws are not only descriptions of nature's established modes of behavior, but are in some way quasi-*controlling* agencies, seems to be prevalent still. To many minds they seem to constitute a kind of invisible, immaterial framework (or complicated railroad track) of the universe, guiding all its events.[12] This view is no doubt a legitimate philosophical conception; but it should not, as is often the case, be presented in the mask of a scientific generalization.

(3) The third view is the *theological*, and is perhaps the most ancient of all. It is the theory that natural laws are simply the *decrees of the Creator and supreme Ruler of the universe*, expressions of unchanging divine will. This is the view which keeps closest to the original signification of the word law; for law is primarily the fixed and authenticated will of an established authority. As soon as the will of the tribe, the monarch, or the parliament is in some

[12] This was evidently the conception of Descartes (cf. p. 95, *supra*, and "Method," Pt. V), except that he regarded these self-acting laws as instituted by personal, that is divine, authority.

way published as a regulation applicable on all occasions of a given kind, it becomes law. From this original, and still common, meaning the idea of natural law doubtless sprang. The uniformities in nature came in time to be regarded as due to the fact that the gods had established a certain order to which they themselves conformed and to which they compelled natural objects to conform; that is, government by natural law then meant that *the gods controlled the world in accordance with their fixed decrees.*[13] This is evidently a perfectly self-consistent and legitimate conception; but however useful it may still be in philosophy, in explanation of the aspects of unity and purposefulness which natural law often bears, it renders little if any service in science. It suggests no means, no mechanism, by which the divine decrees pass into execution; nor is one phenomenon thereby distinguished from another, since all things alike act as they do because "God wills it."[14]

One's decision between these competing views is likely to be decided by individual inclination and type of thought. Only one thing further need be said: No one of them is entitled to wear the garb of science. All are philosophical interpretations. It is in none of these senses that science teaches that the world is governed by law; but merely in the strictly metaphorical one, that things actually behave *as though* they were subject to inflexible rules. For present-day science the real agents are the things

[13] So Cleanthes, the Stoic, exclaimed, "O Zeus, in conformity to law dost thou conduct all things."

[14] A favorite Mohammedan saying.

which "behave." If natural law is a mere description of that behavior, it is evident that it cannot literally govern anything. The universe is not controlled by any kind of *description.* As well might the painter of a battle scene claim to be the victorious general in command.

Final Causes.—It has been noted that the conduct of living things is largely directed by regard for results. Such inciting results, now commonly known as *values,* were formerly called "final causes." The term is not without its propriety, for they certainly seem to be causes in the popular sense of productive agencies, and they are final in the sense that when established the mind asks nothing more *in that direction.* Whatever is good, that is, gives satisfaction or pleasure, is its own warrant for being. Why do men seek money or distinction? Just so far as these ends appear to satisfy the needs and cravings of their nature, just so far do we feel that a sufficient reason has been found.

We come, however, upon a sharp conflict of opinion when we raise the question whether final causes, which are so potent in men and animals, are also actual dynamics (effective agencies) in other parts of nature; whether, for example, regard for consequences has any place in the functionings of molecules at the one extreme, or the development of the universe at the other.[15] The older materialism scouted the notion, and impeached it even as regards living beings. From its point of view, "necessity"

[15] Cf. This second aspect of the question must be left for Part III; cf. *infra,* Chapter XII.

was the sole efficient agency, or dynamic, in the cosmos; and to call an organism a machine, whether animal or man, was to declare that it was driven wholly from behind. All natural processes, it maintained, were entirely fortuitous as regards the future, though completely determined (necessitated) as regards the past. In this contention materialism clearly went too far. Life is too manifestly teleological—directed toward ends—for such a denial.

Life.—To except living things, however, from the reign of necessity obliges the older view to posit a great schism in nature, a gulf between the radically distinct kingdoms of the organic and the inorganic, the one being characterized by the presence of life and its dynamic of value (final cause) and the other by the absence of these. Life on this hypothesis is a most mysterious and baffling factor. It seems to be a godlike agency which takes the blind materials and products of the inorganic world, and fashions them into intelligent, eager, sensitive beings far more removed from their constituent materials than a steamship is from a mass of bog-iron ore. Plant life lays hold upon such elementary substances as oxygen, hydrogen, nitrogen, and carbon builds these up into tissues which animal life is able to transform into oxen and horses, lions and men. Yet once there was no hint nor germ of it in all the physical universe. At some point in the cosmic process the wondrous, artistic agency suddenly appeared; but how? and whence? Not by magic surely, nor by any other breach of continuity; was it, then, by importation from an immaterial world? Such a possibility the true materialist, and indeed the man of science, are very loath to admit.

Of late another view has been growing in favor. It is suggested by the oft-quoted remark of Professor Tyndall that matter, so-called "inanimate matter," contains "the promise and potency of all terrestrial life." It regards the organic domain as simply a more complex and more advanced stage of the so-called inorganic. In it (the organic world) are manifested factors and tendencies which are present, at least in a rudimentary way (in potency if not in actuality)in all existence. According to this view, *all* nature, so far as it is individuated, is, not merely organized, but *in some sense alive.* That is, all existence, on the plane where it shows original activity, acts, or is capable of acting, with reference to ends, values, satisfactions.

Why do infinitesimal individuals,[16] that is, the elementary units of matter, such as atoms, molecules, and cells, act as they do? One may adopt the hypothesis of necessity, and say that they have been eternally determined so that they have to function in those ways; but that is not far from saying that no reason can be given. In the face of this inquiry the newer view resorts to analogy; and, since molecules and atoms appear to be individuals, the analogy is naturally taken from the organic realm, where individuality is a familiar phenomenon. In all living things established functioning is a sure sign of some end served by the function; either an end in the agent

[16] Cf. p. 132 f, *supra*.

so acting, or in some larger system of which it is a part,—often in both. The birth, growth, metabolism, and movements of a cell all have reference to maintaining its life and type, with the resulting satisfactions, together with the life and type and satisfactions of the organism of which it is an integral part. This is so true, that the biologist is not content until he discovers the ends so served. Why may not a kindred explanation, in more rudimentary form, be the truest account of the functionings of molecules, and other physical individuals, also? Certainly analogy to the higher types of individuals seems a sounder method of interpreting the activities of those that are lower than—as was the method of the older materialism—a comparison with physical *masses*, (stones, waters, winds, and so forth) which show no marks of individuality at all.

Thus the view of the old materialism stands for the unbroken reign of necessity; the newer, development, or pluralistic, view stands for the influence of values; the former for action determined purely from behind, the latter for action determined both from behind and also from before—by what is in view. This latter conception involves in all individuals, physical as well as organic, at least a rudimentary consciousness—some feeling of value—since it is the influence of things felt to be in some way valuable, or good, that in part determines action; and the influence of the value factor—the end in view—is regarded as increasing concomitantly with increased organization.

Both Causes and Ends are Valid.—The truth seems to be that both antecedent causes and final causes are proper satisfactions of fundamental human interests, sound answers to legitimate human inquiries. The one class answer the question, how?—the mechanical question; the other class answer the question, what for?—the question of value. The former gratify the analytic-synthetic interest of the mind—its liking for taking things apart and putting them together again; the latter its esthetic interest, its immediate concern with and estimation of things. The former deal with existences as objects with parts and structure, the latter with existences as wholes, and their character irrespective of the underlying articulation and machinery.

Descriptive and Appreciative Knowledge.—These differences in reference and in appeal to our interest are connected with a broad distinction too often overlooked between two distinct kinds of knowledge. Knowledge may be either "descriptive" or "appreciative," to use Professor Royce's terms; it may be primarily either "explanation" or "estimation," in the phraseology of Professor Höffding. Descriptive, or scientific, knowledge is that which is won through the discovery of the causes and other mechanical relations of things; appreciative knowledge is that gained through the immediate response of our organisms to stimuli or through their own inner functioning. It roots in some awareness of value; hence the terms "appreciation" and "estimation." Thus acquaintance with the services rendered the organism by various foods and the mechanical and chemical processes of digestion, might constitute a scientific knowledge of what, aside from the social element, was going on at a banquet; but if the knower of these things was excluded from the feast, especially if he had always been excluded from such scenes, his knowledge would be very one-sided, and with all its extent and accuracy very thin and weak, also.[17] The dullest guest would know much about the viands, and that in a relatively vivid way, which was unknown to him. The contrast is the same on a higher plane when we compare an auditor at a fine symphony who has a thorough acquaintance with the mechanism of sound, but no musical ear, with another at the same performance endowed with keen musical appreciation, but no knowledge of acoustics. As Professor D. S. Miller remarks: "The head analyzes; the heart realizes."

Now, the man of science and still more the mechanical philosopher are tempted to regard descriptive, or scientific, knowledge, since it is the kind which most furthers their ends, as the only kind of knowledge worthy of the name. Two facts, however, should give them pause: (1) The fundamental *materials* of science root in appreciation. Sensations (colors, sounds, flavors, etc.) as such are not descriptive but appreciative in type. (2) At all stages of organic development, from the lowest to the highest, appreciative knowledge is the only kind which moves the will, that is, arouses action. The most perfect description is impotent until it brings before the mind

[17] Cf. the remark of Professor James ("Varieties of Religious Experience," p. 488), quoted from Al-Ghayzali, that to understand the causes of drunkenness, as a physician understands them, is not to be drunk.

some object or situation which appeals in a direct, immediate way to appreciation (feeling). The sanitary expert, the sociologist in reform agitations, and their like, have learned this to their cost; while the orator and the preacher, and especially the musician and the artist, are supposed to have known it always.

Values and Mechanism.—If causes and ends (values) are complementary segments of the area of human interest, each having a corresponding type of knowledge, it would seem that there should be no conflict between the concepts of mechanism and value. The contrary, however, is often assumed. It has been taken for granted that, if the world is indeed a mighty mechanism, or a vast congeries of mechanisms, it cannot exist for any purpose or purposes. Yet in all mechanisms of human construction the two ideas are so far from being in conflict that they are all but inseparable. A man-made machine without a purpose would be regarded as an absurd freak of industry. Nor is the situation very different with natural mechanisms. The machinery of digestion, that of the circulation of the blood, and that of sensation all have reference to ends (and values) which they serve. The like is true of the mechanical adjustments involved in ocean currents and the movements of the planets in the solar system. So far as these constitute established mechanisms, or dynamic systems, they serve ends of material distribution and dynamic equilibrium. In general it may be said that *any object is recognized as a mechanism by the very fact that its established inner* *adjustments and interactions make for some end or purpose.*[18]

The point really doubtful in this connection is whether natural mechanisms are like human ones in serving ends that were *intended* before the construction began, that is, the presence in the world of *conscious* purpose, or *design*. When man constructs a locomotive, he knows beforehand just what end his engine is to serve, and designs it with reference thereto. Was there a Maker of the world who foresaw with equal clearness the ends which the world now actually serves, and intended them? This is indeed a doubtful matter,[19] and present day opinion seems to

[18] On the other hand, the admission of value seeking as a prime dynamic in an individual does not prevent description of its processes in thoroughly mechanical terms. An animal, for example, may be described as a highly complex engine—that is, a machine that develops its own power—adjusted to do certain things, and with its controlling parts in very delicate equilibrium. As a consequence what from the physical point of view is a very small interference suffices to set the engine going in some characteristic way. In the case of man that interference, commonly called the stimulus, is very often some faint or partial repetition in the mechanisn itself of a former inner movement, or function, which was satisfactory, interesting, or pleasing. When such a faint repetition becomes attached to a possible course of action on the part of the organism, it seems to be the slide valve which releases the stored energy in channels leading to that course of action. That potent little repeated inner process, of which some movement in the central nervous system is doubtless the core, the psychologist calls a memory or an idea, as the case may be. The logician calls it a value, for it is something that appeals to the organism and sways it because it is good.

[19] Cf. p. 140, *supra*. This, however, is not necessarily a doubt as to the existence or agency of God, but only as to one theory about his agency, the traditional one of eternal, pre-existent design. As to this it is pertinent to inquire whether the present universe is merely the last of a series of like universes which God has con-

lean to the negative side. The adjustments, interactions and established sequences of the mechanisms of nature may have some other explanation than the antecedent conscious purpose of a personal being. Yet a negative inference is not to be justified by the mere concept of mechanism itself; for both the terms mechanism and the ideas involved in it are, as has been intimated already, drawn from human agency—man's ways of effecting results—and in his machines there is always some prevision of the result to be attained. Lack of any such prevision in a mechanical engineer, would render him the laughing stock of his neighbors, even if they did not shut him up in an asylum as a dangerous character. It is evident, therefore, that the notion of design as underlying cosmic mechanisms is a perfectly legitimate one in itself; whether it is a trustworthy one or not seems to be purely a question of evidence.

It is interesting to note that Descartes, with all his enthusiasm for the mechanical, was far from really eliminating intelligent design and control. He regarded the organization of the universe as coming about mechanically without any design within itself and without any superintending personal guidance from without. On the other hand, an intelligent designer *at the beginning of the present order* is involved in his postulate that matter worked itself into its

structed; for, if it is his first and only attempt, then analogy from human construction in the way of first attempts would not lead us to attribute to him any large advance knowledge of the outcome. In new situations man has to feel his way, and adjust himself to new situations as he meets them. The like may well be the case with the Creator constructing a universe for the first time.

present form under the control of *laws impressed upon it by God.*[20] As to the mechanism of the human body he held it to be controlled by a rational soul seated within it and using it for intelligent purposes like the modern engineer in a locomotive.

Exercises

1. Give five examples of natural laws, stating them with precision, and show in what sense they are constructions rather than discoveries. What two kinds of things expressed in them have been discovered?

2. Give a critical account of the standing of natural laws in science, and show on what sub-principle or postulate of mechanism they are based and to what primary methodological principle they are subject.

3. Mention five (original) cases of animal-action with a view to results, and contrast them with five cases of the action of natural agencies that seem necessitated.

4. Describe five situations or processes within plant or animal organisms in regard to which the consideration of final causes, or ends served, is requisite for a satisfactory explanation. Show how in these cases mechanism is nevertheless involved.

5. Show what Whetham means by calling our knowledge of nature a "model" or "chart." (Cf "Recent Devels. of Phys. Science," chap. I.)

6. Read Darwin's "Life," etc., chap. II, pp. 81–83, and point out what kind of knowledge became difficult to him and why, and in what kind he gained great power. Give examples of each kind drawn from his career.

[20] "Method," Pt. V. Cf. p. 95, *supra*. Cf. also the following statement of Professor Huxley: "The teleological and the mechanical views of nature are not necessarily mutually exclusive. On the contrary, the more purely a mechanist the spectator is, the more firmly does he affirm primordial nebular arrangement, of which all the phenomena of the universe are consequences, the more completely is he thereby at the mercy of the teleologist, who can always defy him to disprove that this primordial nebular arrangement was not intended to evolve the phenomena of the universe."—"Critiques," p. 274.

CHAPTER X

EVOLUTION

The two sciences of geology and biology have worked a revolution in a little over half a century in our thoughts of the world in which we live. From geology we have learned that the earth was not always what it is now, nor will it remain in its present state. It has a history (which is the science of geology) and it is now making, and it will in future make, further material for its history. The most notable feature of that history is the broad fact that for countless ages past the earth changes have been on the whole in the direction of increased complexity and higher[1] organization. Another significant feature of the earth history is the fact that living things are, comparatively speaking, recent comers upon the earth, and that their first appearances here have constituted an age-long series of new arrivals. At intervals through hundreds of thousands of years new organic types have been appearing. This series of arrivals, also, takes on an orderly and progressive character when viewed from the standpoint

[1] This word is sometimes challenged as inappropriate in natural descriptions. Nature, it is urged, knows no difference of higher and lower, that is, of value; but all conditions are equally good and high to it. However this may be, the term in the text is at least justifiable from man's point of view. By "higher organization" is meant the arrangement of things which yields richer values to sentient beings.

of organization; for, with rare exceptions, the later types are the more highly organized, and the earlier the simpler. The long earth story is thus one of orderly and *progressive* change, of persistent production of higher types, that is, of *development.*

Of late this geological story has been taken up in a remarkable way by the biological sciences; for they favor the belief that the new forms of life thus appearing from time to time are not new creations, as was once thought, but are really modifications of, and in a sense improvements on, earlier organic forms. The formidable octopus is the descendant through long generations of a minute gelatinous creature constituted of a single cell; the powerful Percheron horse of to-day is the direct, though greatly modified, descendant of an archaic pigmy quadruped with four or five toes instead of one; while man himself must trace his lineage back to a tree-dwelling animal not unlike one of the larger apes. The long process of modification and development through which these newer and higher types have been produced has received the name of *evolution.*

The student is, of course, aware that evolution is to-day a word of power and promise. It is already the key to many a natural arcanum, and seems likely to unlock other recesses that are still closed and dark. Perhaps no other principle has proved so serviceable, unless it be that of mechanism, a concept of which it is in part the antithesis, in part the complement. Mechanism emphasizes the determinateness and fixity of nature, and evolution its plasticity and progressiveness; mechanism represents the world as it is at any given moment, evolution indicates how it came to be what it is.

Yet the evolutionary conception has met with much opposition,—at first in scientific circles, and still in those of theology. It has been declared incredible that life should thus climb from low and simple beginnings, and shape itself at length into the amazingly complex forms of the higher organisms. How far removed is Napoleon from a jelly-fish! And truly the marvel which the theory requires us to accept is neither to be denied nor disparaged. Yet it is far from incredible, for the reason that it is supported by the analogy of another and incontestable wonder which is even greater, the familiar wonder of the growth of animals and plants from an egg or seed. How is it that the fertilized egg of a bird or fowl, kept certain weeks at a definite temperature and turned daily, will *of itself* develop into an elaborately organized being like its parents? This, ever since man became a reflective being has been a baffling problem, a perpetual miracle. Only of late has any answer worthy to be called scientific been returned, and still the answer is all too imperfect. The biologist has discovered that in each such case an established, orderly process of gradual and progressive change is involved. It starts with a tiny organic individual called a cell, which under proper conditions of heat and moisture awakes to active life, soon dividing itself into two "daughter cells," each of which is as much alive and capable of reproduction as was the vanished mother. This process of bifurcation, or "fission," is repeated again and again, until the number of living cells is sufficiently great, whereupon they arrange themselves in a kind of web of two or three layers. The next stage is one of the enfolding of the layer on one side of the web by that on the other, so that a sac is formed with an open mouth opposite the central portion of the enfolded layer. The process of cell multiplication continues, but combined with it now are specializations of function. The daughter cells are no longer, even to the eye of the observer, mere duplications of the mother, but differ in appearance and function more and more. The series of changes is much too long and intricate to be followed in these pages in detail, but that they are true mechanical links in a chain of purposive, or teleogical, processes may be illustrated by the simple statement that the changes which occur within the sac, or *gastrula*, all work toward the production of the viscera of the developing animal, while those occurring in the outer (and middle) layers of cells go to produce its bones and muscular parts.

Now these changes *seem* to take place of themselves when certain relatively simple conditions—as of heat, moisture and support—are supplied. Of course this seeming may be deceptive, and there may be an invisible and enduring agent of intelligent control present. The biologist's knowledge does not enable him to declare confidently as to this possibility;[2] but at least the accredited facts as to *individual*

[2] The complete absence of any such enduring agent leaves the orderly constructiveness of the individual genetic process a baffling problem; for during that expanding creative process all the con-

genesis and growth furnish ample analogical warrant for accepting at least a *seeming* self-development in the case of the genesis of new species. If the phylogeny, that is, the evolution of a *species* from a simpler form of life, is wonderful, as it assuredly is, it is but a similar and less extreme wonder to that of the ontogeny—the origin within *a few weeks or months* of individuals of those higher orders from the seemingly simple substance of the fertilized egg.

The first to make important contributions to the phylogenetic problem—that of the origin of species—were the biologists, Lamarck [3] and Treviranus,[4] who lived in the early part of the nineteenth century. Lamarck maintained that specific types were simply the natural modifications in the course of descent of a common generic ancestral form. The resemblances between the members of a species he accounted for by the principle of heredity; that is, in these respects the ancestral type had been bequeathed unchanged. The differences between the species of a common genus he explained by pointing to the influence of use and disuse upon the structure of the organs of animals and plants. His first contention—common descent as the secret of specific likenesses—may be said to be established. It is a familiar

stituent cells are born and die again in all but countless generations. As Professor Wilson remarks ("The Cell," p. 328), "Any theory we can frame demands for the orderly distribution of the elements of the germ-plasm a prearranged system of forces of absolutely inconceivable complexity."

[3] Lamarck (1744–1829), a celebrated French naturalist, was professor of natural history at the Jardin des Plantes in Paris.

[4] Treviranus (1776–1837) was a German naturalist of distinction.

fact that constitutional characteristics are hereditary;[5] the children, whether of men or animals, are apt to resemble their parents, and so to resemble each other, also. Though this is not an invariable rule owing to the extreme complexity of family stocks, yet commonly we do discover a family likeness in the offspring of the same pair. Turning this principle around and reading the unknown past by means of it, Lamarck argued reasonably enough that extensive similarities in organisms are evidence of their descent from the same original ancestors. So far present-day biologists agree with him.

His second principle, that of the structural modification of organs through use, is more doubtful. It is indeed true that use and disuse affect the development and type of organic parts. The working ox has hard tissues which make poor beef just *because* it works. If it had been kept in meadow and stall until slaughtered, its flesh would have made far better food. A dog is naturally a swift-footed animal, but the pampered lap-dog often becomes incapable of running any considerable distance. The eye of the hawk and the eagle is sharpened by vigilant use, as are also the wits of a man. Lamarck argued that the individual differences in living things which arise in such ways, being handed down

[5] Heredity may be regarded as a quasi-extension of the principle of habit from the single individual to the race lineally viewed. Just as the individual finds it easier to do what it has done before, and, under similar circumstances, tends to do that thing rather than another, so the reproductive processes to which the succeeding generations are due tend to repeat the type of one or both of the parents.

to the offspring by heredity, would often be increased in degree and fixed in the family stock by the repetitions of use or disuse which natural conditions might bring about. Thus the ancestors of the giraffe might not have excelled a horse or a zebra in length of neck; but if they inhabited a district where grass was lacking most of the year and food was to be obtained only by browsing from the trees, then the continual reaching up to the branches on the part of generation after generation of these animals might quite possibly result in a permanent elongation of the neck such as we now see in the giraffe.

This theory had a very plausible sound, but a serious and probably fatal difficulty transpired in the course of time; for acquired characteristics (modified organs, etc.) are either not hereditary, or hereditary in such a minor degree as to furnish no adequate explanation of the origin of new forms of life. A man who is *by nature* of athletic build may transmit that physical characteristic to his children, and is very apt to do so if his wife is also *naturally* of a superior physical type; but if *constitutionally* the pair have merely ordinary physiques and develop athletic proficiency *through training*, there appears to be no constitutional tendency in their children to excel in that respect. Nature is very chary, if not utterly refractory, about adopting acquired characteristics for addition to the hereditary family stock.

Natural Selection.—Evolution in our time is associated, not with Lamarck, but with the great name of Charles Darwin, whose doctrine of *natural selection*, worked out with utmost care and fine intelligence, outlined a probable natural mechanism by which the origin of species could be accounted for on evolutionary lines. Artificial selection was, of course, a familiar process in Darwin's day, as it is still. It consists in the repeated choice generation after generation, on the part of a breeder of plants or animals, of those specimens for reproductive purposes which possess in largest measure some desired characteristic. A breeder who wishes to develop a stronger draught horse will select for breeding purposes only those stallions and mares which have the heaviest bones and the stoutest muscles and sinews. He will see to it that these specimens leave issue while the inferior horses do not; and so on for several generations of horses. Now, Darwin's great thought was that, in a blinder and consequently slower way, ordinary physical factors in the environment of living forms, such as the limitation of food supply and the severities and changes of climate, have always been acting upon them as selecting agencies, killing off the weaker and otherwise unfit individuals, and leaving only the more vigorous (or otherwise especially adapted) to transmit their types to posterity. Nature, on this view, has unconsciously acted like a wise but unsparing gardener, who causes his beds to show only vigorous plants by pulling up the weaker ones.

In this notable theory Darwin relied upon three principles.

(1) *Struggle for Existence.* In general organisms multiply faster than their means of subsistence.

When the food supply falls short of what is needed for the proper support of all the individuals of a species, a competitive struggle between them for the possession of food takes place, a struggle which may be a literal combat or, as in the case of plants, merely a more successful appropriation of the food. In either case, many of the less fit perish, and leave no descendants. Furthermore, all living things hold to life by a tenure more or less frail. Besides the familiar adversities of climate, every living type has its living foes, either in the form of other organisms which use it for food or of parasites who seek it as places of abode. Continued existence is the prize of success in the warfare with environment, living and physical, a warfare which is far more general and severe than ordinary casual observation would indicate. It is the strongest, the swiftest, the best adapted to heat or cold, or the best qualified in other ways, who hold on to life.

Every experienced lumberman has observed a striking result of this struggle. He may have little enough idea of the organic conflict going on under his eyes, but he is familiar with the fact that when he cuts off a tract of virgin forest—in the north generally made up of evergreens—the volunteer growth that springs up among the stumps is different in type from that which fell before his ax. Hardwoods commonly follow an evergreen growth, though at times one kind of evergreen succeeds another. Cedars may follow hemlocks, for example. The secret of this change appears to be that the natural conditions, both of climate and soil, have changed since the virgin forest arose, and another form of growth is now better fitted to reach light and water and to resist heat and drought, than the great conifers which once held all but absolute sway.

(2) *Variation.* But *why* do some individuals prove better able than others to secure food, withstand hardship, or maintain themselves in combat? Sometimes, of course, the difference is due to superior accidental advantages at the outset. Very often, however, it is due to constitutional differences which cannot be accounted for, differences which the biologist calls *variations* of type. Though the individuals of a species of course resemble each other in the main, yet always there are differences. These in many cases are of no practical moment; but sometimes, even when slight, they are of great importance, for through them the possessor is enabled to survive amidst adverse conditions. The tendency—an inveterate one—of organisms to differ slightly from their fellows, that is, to vary in type, is what is meant by the principle of *variation.* It is evidently a necessary factor in natural selection; for, if natural processes are to select some individuals because of their special fitness to survive, those specially fit individuals must first exist; that is, must first be produced in the course of ordinary generation.

(3) It is evident, however, that natural selection would not create a type if the superior characteristics of survivors were not transmitted to their offspring, that is, if struggle for existence and variation were not supplemented by the action of heredity—the first of Lamarck's two explanatory principles.

But with this principle bearing sway in the field of life, we have only to suppose that in a natural situation which tests radically the fitness of some species to survive, the unfit are completely eliminated by death, to make it evident that the superior individuals who survive will most likely bequeath their favorable characteristics as a permanent vital heritage to the generations that follow. In the original successful competitors those characteristics were new qualities, novel functions or relatively so; in the descendants, through many repetitions, they become fixed features, integral parts of the type. So heredity completes the work of variation and struggle for existence.

Now, these principles are known to be actual working factors in the natural world; and it is clear, consequently, that under their sway, through the accumulation of characteristics in this way, there may well have been in the long ages since life appeared on the earth, a fairly continuous progress of organic forms from the lowest beginnings in the direction of increased adaptation to natural conditions, an adaptation involving either new adjustments or larger efficiency or both. Such a progress would naturally be toward wider differences in type and greater complexity of organization; for under diverse physical conditions—climate, altitude, etc.—quite different variations in the same original stock will prove serviceable for survival, and will be "selected" and incorporated in the type.

Natural Selection not Ideal Evolution.—It is not easy to exaggerate the service which this theory has rendered to the biological sciences. It has brought light and clearness into fields that before were obscure, continuity and order where before was a meaningless medley. It has furnished helpful interpretative analogies to other departments of inquiry, also, and is likely to continue to do so.

As an evolutionary scheme it evidently lies between the extremes of absolutism and the old materialism. There is in it no suggestion of the unbroken sway of "necessity" and the mechanics of pure impact. These may be real enough in certain of its physical conditions, such as cold and drought; but the organic agents, those which "struggle," survive, and leave offspring, are moved by a sense of value, a craving for the satisfactions of life—food, security, ease, and so forth—and the forces which respond to these values are within the agents, not behind them. Inert objects do not struggle.

On the other hand, a development by such a process does not bear the aspect of design. It is hard to believe that a Being who had clearly in view in advance the purpose of producing the species that now exist would, at least *if He was in full control*, have chosen this relatively haphazard method of realizing it, a method so wasteful of life and seemingly so indifferent to inflicted pain. The story of natural selection is a tragic epic, according to which existence has *groped* its way, at the cost of untold toil and suffering, upward to higher grades of being; it has not unfolded in a well-considered way according either to a foreordained plan or the necessary unfolding of any symmetrical system of forces.

Cosmic Evolutionism.—The success which has attended the theory of natural selection in the organic field has led many in our day to the belief that the key which is to unlock the secret of the universe as a whole must be some sort of evolutionary one. The world—earth and planets, sun and stars—evidently was not always what it is now; may it not be that, instead of being the detailed product of an outside Creator, or possibly the outcome of fortuitous and meaningless forces, it is continually unfolding from a potential initial condition?

The thought is far from new. Heraclitus [6] and the Stoics,[7] Democritus and others, taught doctrines more or less akin to it. Yet it did not find hearty acceptance among ancient thinkers, they being too strongly impressed by the seemingly changeless aspects of existence. How firm and constant was the earth under foot! how immutable the mountains and the sky (the firmament)! And even the changeful things, seas and clouds, plants and animals, were constant in their *perpetually recurring types*, indicating that beneath or behind the mutable objects of sense there was changeless existence.[8] With the later thinkers of antiquity the doctrine of emanation be-

[6] Heraclitus (abt. 535–abt. 475 B. C.) was a remarkable Greek philosopher of Ephesus in Asia Minor. He championed the idea that process is the fundamental reality in the world, and that nothing is fixed except the type of the process. He anticipated the modern evolutionary conception of descent with modifications.

[7] The Stoics, a Greek philosophical school founded by Zeno about 308 B. C., looked to Heraclitus as their great authority as to nature. To his metaphysics they joined a broadened type of austere cynic ethics.

[8] This was Plato's most distinctive conception.

came the favorite view, the theory that complete and perfect existence is at the *beginning* of the change process, not the end. That ideal existence is the *first cause*, or *source*, of all forms of phenomena, and every step in the change process away from that eternal source is a step *down* in the grade of being, a declension not a development.[9] Of course, ancient observers were familiar with seeds and eggs and their growth; but they commonly thought of these things as incidents *within* the fixed framework of the world, epicycles upon a larger eternal round of natural process, a relation like that of the waxing and waning day (morning, noon, and night) and the waxing and waning year to the unchanging movement (as it seemed then) of the heavens about the earth.

Even in later evolutionary theories the disposition has always been strong to hold to an unchanging framework, though when it came to be known that changes occur in the very rocks and mountains, and that neither earth nor sun is fixed, it became necessary to think of that framework as immaterial, that is, as either a changeless (Platonic) type or an eternal law of some kind.[10] Spinoza, following the Neo-Platonists of the third century, taught that all things are unfoldings of one highly potential substance, which perpetually produces every sort of thing that is possible. The substance is rigidly bound, however, by its determinations, or character, or law, nothing whatever being metaphysically free; and so at any given time only those new things are possible which

[9] Cf. the cosmology of the Neo-Platonists.

[10] Cf. p. 160 f, *supra*, for the discussion of these concepts.

either are not in conflict with the things already in existence or are able to win out in such a conflict. By means of these assumptions, Spinoza gives us a striking picture of the continual evolution from potential substance to actual existences which, as he holds, goes on unceasingly, without beginning and without end, within the limits of immutable natural law. No source of the law is named, or admitted as possible; it is the eternal, rigid case within which the watch of the evolutionary process forever ticks.[11]

Others have represented the evolutionary process as due to the will of the Deity who is working out his unchanging design as the ages pass,—

> "One God, one law, one element,
> And one far-off divine event,
> To which the whole creation moves."

In this conception the evolutionary element bulks larger than in that of Spinoza, the changeless factor being now located above and beyond the world, which itself is perpetually in the act of passing on from stage to stage of existence, each higher than the last. In all such doctrines, whether theistic or pantheistic, the element of immanent control, that is, of complete internal guidance in accordance with some idea or purpose, is the salient thing. In this respect they are all to be contrasted with natural selection, in

[11] The evolutionism of Leibniz, though more ideal is similar in this respect. On the other hand, some present-day evolutionists think that the "laws" (determinations) are products of the evolutionary process—a complete reversal of the ancient conception, the seemingly permanent aspects of the world thus being reduced to the position of incidents of the change process.

which the intelligent or ideal factor is represented as very limited in its scope, and as groping its way along a course determined for it largely by what seem to be accidental circumstances.

Spencer's Evolutionism.—Herbert Spencer was the first thinker to develop systematically the notion of cosmic evolution *in a quasi-scientific way;* that is, to outline a mechanical process of *world* development in close accord with the accredited facts and laws of modern physical science. He assumes an ultimate *dynamic existence* which is infinite in extent and therefore incapable of organization into a systematic whole, that is, of complete dynamic equilibrium; and offers as his thesis the proposition that development is the method by which in every field this ultimate existence works itself out into manifestation in our world. His field of inquiry thus becomes the processes by which this fundamental existence, which of course is imperceptible to us, passes into the integrated and complex types which we know as the objects of sense. His theory, to use his own words, concerns the "passage of the imperceptible into the perceptible," a passage which he finds to be characterized by "loss of motion and consequent integration." By loss of motion he does not mean an absolute loss, for all existence is characterized by motion, but the elimination, in greater or less degree, from certain situations or areas of existence of such movements as tend to keep particles of matter apart. These are either transformed or pass on to other objects. As a consequence only that which causes or permits close association of the particles remains; and existence is left in a more coherent state. On the other hand, it is now less homogeneous. Motion does not depart or suffer transformation at the same rate in all the parts of a coherent mass, and the differences in this respect become intensified as effects are accumulated. What process, for example, is seemingly more simple and uniform than that of the cooling of a glowing body; yet in the case of the cooling earth, owing to the fact that the later contractions of the crust had to deal with earlier, albeit comparatively minor, differences of thickness and strength, they have produced for us a remarkable variety of mountain ranges and ocean depths.

There are thus in the Spencerian theory two subprinciples involved in the passage of the imperceptible into the perceptible, with the resulting integration. One of these is the principle of the "instability of the homogeneous," the other that of the "multiplication of effects." Both are involved in the illustration of the cooling earth, the meaning of "multiplication of effects" having been indicated above. As to the first principle named, if we suppose the earth to have been once a perfectly homogeneous liquid (molten) or gaseous sphere, it is evident that under the inevitable conditions of an infinite, and so not equilibrated, universe, it could not remain homogeneous. It would not cool uniformly through radiation, *partly* because it is constantly receiving new heat from the sun, and in differing measure on its various parts according to the varying angles of incidence presented by its curved surface; *partly* because its orbit is not a circle, and it consequently varies in its distance from the sun; *partly*, again, because its axis is not perpendicular to the ecliptic, and so the northern and southern hemispheres present different angles to the sun's rays; and *partly*, finally, because, being a rotating body, it is necessarily of shorter diameter through the poles than through the equator, and so will lose heat faster in its polar regions. So, Mr. Spencer argues, in an infinite universe a homogeneous body cannot remain such; or, at least, it is subject to many influences to make it heterogeneous. By means of these two principles he succeeds in accounting mechanically for certainly a very large part of the vast diversity of the universe.

We have, then, from Mr. Spencer an account of how a supposed homogeneous, dynamic existence would inevitably, according to known mechanical principles, become coherent in mass, varied in type, and fixed in character. It is an interesting account, and no doubt an evolutionary one, so far as it goes. Nevertheless, it leaves much to be desired. It is very general, for one thing, presenting only certain major phases of the cosmic process. A more serious drawback, however, is the limitations—apparently arbitrary—which it puts upon the field of inquiry. Spencer offers no suggestion as to why things act at all; why, for example, all organisms strive for continued existence. All such inquiries he regards as unanswerable—essentially religious. They are attempts to penetrate the unknowable, to lift the veil of Isis, and must be scientifically fruitless. On the contrary, he holds that we must make *two fundamen-*

tal assumptions: (1) That there is an *absolute, infinite, unknowable existence* which is *the source and background of all phenomena;* and (2) that there is, also, an *absolute, underived law, or principle,* namely, *the persistence of force,* the persistence being entirely blind and completely determinate.

For *assumptions* these appear to be large philosophical statements. The second is evidently the old doctrine of physical necessity [12] in modern guise; and we have seen already that the hypothesis of force as "necessary" is not a coercive one, and is only to be accepted in case it gives the best explanation of the world. The first assumption reminds us at once of the Neo-Platonic theory of an eternal, infinite, unknowable Fountain of all existence. It seems to be Spinoza's theory in nineteenth century language. It has repeatedly been remarked that though Spencer holds that ultimate existence is unknowable to men, yet the philosopher himself somehow knows that it is infinite, dynamic, determinate, and probably most like what wells up in us in consciousness! A more fundamental objection is that the very notion is self-contradictory, for a thing can be known to exist only by in some measure knowing it.[13]

[12] Cf. p. 156, *supra*.

[13] Nor can any present facts or principles be known as necessary limits to knowledge; for to know any object, line, or point, as a limit requires a knowledge of something lying beyond it. This *in the case of a limit to knowledge* would be self-contradictory. There are doubtless impassable limits to our knowledge, but in the nature of the case we are unaware of what and where they are. Cf. the remark of Hegel: "No one is aware that anything is a limit or defect until at the same time he is above and beyond it."

Exercises

1. Describe three (original) cases in which Lamarck's theory might seem to account for striking plant or animal types.

2. Give five cases (15 in all) illustrating each of the sub-principles involved in natural selection, and showing that these principles are valid quite apart from Darwin's noted theory.

3. Describe five cases of evident adaptation to environment, and show how Darwin's theory will account for them.

4. Describe two (original) cases of what Spencer calls the "instability of the homogeneous." Examples might be taken from meteorology and mechanics.

5. Do the same with the principle of the "multiplication of effects."

6. After referring to a good history of philosophy, or other work on the subject, outline Spinoza's theory of the world process, and show how far the evolutionary idea enters into his system.

7. Expand into prose detail and something like system the evolutionary idea suggested in the last six stanzas of Tennyson's "In Memoriam."

PART III

BASAL PRINCIPLES

CHAPTER XI

POSTULATES

Descartes tells us that he concluded he "ought to reject as absolutely false all opinions in regard to which [he] could suppose the least ground for doubt, in order to ascertain whether after that there remained aught in [his] belief that was wholly indubitable."[1] On the same page, however, he remarks "that, *in relation to practice,* it is sometimes necessary to adopt, as if above doubt, opinions which we discover to be highly uncertain."[2] This is by way of explanation of the fact that he had framed certain rules for his guidance in the world before he had convinced himself that there was any world, or that the rules would always lead him aright. For example, he determined *in ordinary affairs* to act and believe as did men in general around him, thereby, of course adopting moderate rather than radical views. Yet he did not know that the moderate views would prove true. Another of his maxims was, to hold firmly to his course, *in other than scientific matters,* both in action and opinions regardless of doubts.[3] Yet he could not deny that this course might lead him into error.

[1] "Method," Pt. IV. [2] Cf. *id.*, Pt. III.

[3] *Id.*, Pt. III. His third practical maxim was the Stoical one of adjusting himself to circumstances whenever he could not shape these to his liking.

The justification of it was, that it would lead him somewhere, while a vacillating course was likely to lead nowhere.

These maxims he felt it to be sound wisdom to adopt for the reason that *in practical affairs* he was not free—as he was in scientific matters—to give full rein to doubt, and make the pursuit of indubitable reality his supreme aim. In order to investigate at all, it was necessary first to live; [4] and life makes immediate demands upon us, demands which must be met somehow *in the present*, not after we have made all the inquiries which logically precede them. Hence Descartes adopted his prudent maxims, each of which from the point of view of his principle of rigor involved an assumption.

This situation was not peculiar to him. All men of science are obliged to make assumptions. They cannot begin their investigations at the foundations of the universe, and refuse to believe anything, *or to act as though they believed anything*, until every fact and principle from the bottom up is demonstrated to their satisfaction. They find themselves in the world in the thick of action and belief. Life has been going on for untold ages. When the inquirer begins to think critically, he already has a considerable stock of beliefs, some of which are theoretical (opinions), but others of which are practical, that is, *beliefs on which he acts*. Later, after he has

[4] Cf. the remark of Dr. F. C. S. Schiller as to "the sangfroid of Descartes when he set himself to doubt methodically everything that existed, but resolved meanwhile not to change his dinner-hour!"—"Studies in Humanism," p. 395.

pushed his inquiries far and wide in a critical spirit, he is often able to look back and see that some of the conceptions on which he began as a man to act and as a scientist to experiment were more or less erroneous; but this he could not see in advance. He had to go ahead, using the ideas that *seemed* to him true, or most likely to be true. On the other hand, some of his initial ideas, even after the utmost research, he finds indispensable still, and that albeit they are still unproved. They are indispensable because without them he cannot justify logically the scientific processes which have led him to repeated discoveries. Such needful ideas, taken for granted at the outset, and still remaining requisite at each stage of inquiry, may properly be called the *basal principles* of science. As we saw in the first part of our study,[5] they are not primarily its discoveries, nor yet its methods; but are rather in a way a part of its data. They have been variously termed *axioms, fundamental assumptions*, and *ultimate postulates.*

Axioms.—An axiom is generally defined as the statement of a self-evident truth, such as the assertion that the whole is greater than any one of its parts. Its self-evidence, that is, its character as immediate knowledge, is what distinguishes it from assumptions, postulates, and hypotheses. The latter do not have this character, but are entertained primarily without proof of any kind, and without being regarded as parts of knowlege proper. Axioms are, of course, accepted by science without question, and used as parts of its working material. They

[5] Cf. p. 27 f, *supra.*

are often thought to be uniquely rational, and so essentially different from immediate knowledge, (intuitions) of the sensory sorts—colors, sounds, pressures, etc.—but it may be doubted if the difference goes farther than the fact that they are immediate perceptions of *relation*, while sensory intuitions are immediate perceptions of *quality*. It is open to question, also, whether they have not developed as man became reflective from much vaguer relational perceptions (in primitive man) which were not immediate, but were really postulates which experience increasingly confirmed. That two straight lines in a plane cannot inclose a surface may well have started out in human thought as a mere vague feeling, a feeling which for a score or more of generations had to be proved in experience before it was fully trusted. Now, of course, following the uniform experience of long ages, that insight has become a quasi-instinctive functioning of our minds when they reach a certain maturity, and it is no longer a postulate but an axiom.

Basal Assumptions, or Fundamental Postulates.—In general an assumption is, of course, some idea or statement which is accepted as true, at least provisionally, without proof. Originally a postulate was merely a *preliminary* assumption adopted as a means of deduction, just as a hypothesis was a *working* assumption adopted as a means of explanation. Of late, following the German usage, it has been common to distinguish the postulate somewhat further, and to regard it as a preliminary *practical* assumption. That is, it is a proposition which asserts without proof that something can be *done*. Thus Euclid's first postulate asserts that between any two points a straight line *can be drawn*.

Making use of this distinction, the basal ideas, or fundamental assumptions, of science appear to be essentially postulates. They are preliminary *practical* assumptions, having always a reference to something that can be done. The postulate of the uniformity of nature, for example, means for science that the world is so constituted that upon a sufficient acquaintance with present conditions *one can predict* the future, that is *can count on* the future behavior of natural objects.

This forward pointing of the mind suggests why fundamental postulates are so readily accepted: (1) For one thing, they appear to be the *necessary starting points* of science and a progressive control of nature; and we are very loath to believe that either of these is beyond us. In other words, we have so much at stake in the possibilities offered by the postulates that we are *ready to believe*. Faith is an instinctive attitude of the mind when progress is in question. It is often a surprise to students to find that faith is a factor, and an indispensable one, in scientific knowledge; but the fact is no ground for skepticism or destructive criticism. Man as an active being is naturally interested in and drawn to statements that offer scope for action.

(2) A further reason for the ready acceptance of scientific postulates is that as practical *they* naturally *lead to their own justification*. There is, of course, a hazard in accepting without proof any proposition

whatever; but in the case of assumptions that seem to be needful for imperative practical ends it is not serious. Since they refer to some kind of action as possible, taking them so to speak in their own spirit is to act upon them, and so to test them; and that is speedily to ascertain their truth (or error), or at least their validity. In other words, an assumption which points to a line of action (a postulate) does not need *a priori* proof, because in the nature of the case is so susceptible of proof, or at least confirmation, *a postiori*. The successful application of it is its vindication. It was in this spirit that Columbus made his memorable voyage. He did not, and could not, wait until the sphericity of the earth was scientifically demonstrated; for his voyage (or its equivalent) was an important and perhaps indispensable part of the scientific demonstration. In this respect the great explorer was typical of the man of science, who is very ready to act upon practical assumptions. The unknown is so attractive that he is ready to try any plan, that is, act on any assumption, which gives promise of leading to it. Thereby he, of course, puts a certain tentative faith in them in advance of proof,[6] but in the long run he finds that such cautious belief giving is abundantly justified by the results gained.

The faith attitude toward practical assumptions that appear to be useful is, of course, not peculiar to science, but is characteristic of life in general.

[6] Indeed, every experiment may be regarded as a concrete (provisional) postulate. It says in act—at least until the outcome disproves it—this procedure will effect the desired result.

In perception we trust our senses until we find some reason to doubt them, while in commerce and industry we form conclusions as to the future upon which we act, although aware that they may be erroneous. The manufacturer works up raw material into goods, with only probability as to future demand to guide him, and the merchant sends forth ship-loads of valuable freight with no absolute guarantee against hurricane or reef or collision, and the nation builds a ship-canal between two great bodies of water, although it cannot prove that its ditches and dams will withstand the untried strains upon them, nor indeed that ocean currents and lunar influences will be in the future just what they have been in the past.

It thus appears that the field of science proper, that is, of sure processes and clear, verified, universal knowledge, is quite a limited one, a field set between two other domains in each of which knowledge shades off into belief; namely, the domain of common life on the one hand, and on the other that of fundamental metaphysical ideas, or ultimate convictions as to the universe.

Exercises

1. In what sciences do the following non-fundamental postulates lie at the threshold of inquiry? Point out in each case how they come to be assumed:—

   (1) The processes of a living body are to be explained by the properties and laws of matter.

   (2) Through any two points a straight line can be drawn.

   (3) All material things may be regarded as constituted of

one or more of some fourscore natural substances called elements.

(4) All mechanical phenomena may be described in terms of matter, motion, space, and time.

(5) The movements of the heavenly bodies are to be interpreted by the physical laws known to hold good on the earth.

(6) The changes which the earth has undergone in the remote past are to be interpreted by the processes now at work in it.

(7) The mental processes of other men are to be understood by a critical study of one's own thinking.

2. On what explorer's postulate did Stanley proceed in his famous journey across equatorial Africa westward from Lake Tanganyika. Show in what sense the postulate was a mental venture, and what was the justification of that venture.

3. What is the implicit postulate of the ship captain who puts forth on the ocean, it may be under persistently cloudy skies, for a port beyond the sea?

4. Give five examples of postulates involved in other human callings.

5. As living, growing, and aging beings men are continually acting upon a fundamental life postulate. State that postulate to the best of your ability.

CHAPTER XII

RATIONALITY OF THE WORLD

The primary postulates of physical science seem to be four,—the uniformity of nature, the rationality of the universe, the objective reality of the physical world, and the actuality of space and time. For our purposes, however, it will be convenient to reduce these to two,[1] namely, (1) the rationality of the world and (2) its objective actuality.

Rationality of the World.—Physical science proceeds on the working basis that the processes of nature are comprehensible by the human mind. This assumption is implicit in the very act of natural inquiry, for, if one believes nature cannot be understood he will not undertake the toilsome investigations required for the exploration of her mysteries. The ancient Greek philosophers of the school of Pyrrho,[2] known as the Skeptics, together with the Sophists [3] before them, denied that men were capable

[1] Uniformity, as we shall see, may well be regarded as a kind of rationality, while the objectivity of space and time is involved in that of the physical world.

[2] Pyrrho (abt. 360–abt. 270 B. C.) was the Greek philosopher who founded the ancient skeptical school. He taught that nothing regarding nature or life could be really known and that wisdom consisted in a suspense of judgment.

[3] The Sophists (or wise men) were the first thorough-going philosophical critics. They arose in Grecian lands in the fifth century, B. C., after the close of the Persian war. Their motto was, "Know Thyself." Protagoras was their greatest thinker and Socrates their finest product.

of knowing the real facts and truths of the natural world, and, by a natural consequence, with all their acuteness of mind, no discoveries in natural science are to be placed to their credit. The man who (intentionally) accomplishes things is the man who believes they are possible; he is, in a sense, the man of *faith*. The principle of rationality is therefore a postulate in the sense adopted in the last chapter.

In the *inductive* processes of discovery this postulate is to be recognized in the persistence with which scientific thought applies hypothesis after hypothesis to mysterious phenomena. Back of this continual trying at nature's puzzles is evidently the confidence that some form of human thinking will be found to fit the facts; or, as Professor Huxley once expressed it, the confidence that "nature will not put us to permanent intellectual confusion." In *deductive* processes the same rationality postulate appears in the confidence with which men of science apply its laws, which of course have been formed by themselves and their fellows, to new cases and new situations in which they have had no experience of their validity. Mr. Edison, for example, went through long periods of patient experimentation in the belief that, if oxygen could be excluded from his lamp, the carbon filament through which he planned to pass the electric current could be made to glow indefinitely; yet this was a phenomenon which at the time he had never witnessed. He *believed* in the outcome, because he had confidence that the laws of combustion were parts of an orderly system.

The fundamental idea involved in the notion of rationality seems to be that of coherence or consistency. Certain things or facts—both objects and relations—are impressed upon us immediately by our mere contact with the world. These are the "impressions" and customary "conjunctions" of Hume, which psychology now calls sensations, relational "fringe," and empirical associations; and they constitute the empirical data with which the mind works. As data they are non-rational, or "brute facts"; but, as it has often happened that the data of one generation have been analyzed and comprehended by the next generation, we cannot be sure that our present data will be non-rational for those who come after us. With these as a basis, comprehension of the world seems to consist, on the one hand, in bringing these data into a kind of mental accord, and, on the other, in resolving all complex facts into them; as, for example, in recognizing in salts, acids, and bases simply combinations of the physical data, or elements, with their characteristic reactions. Intellectual comprehension is essentially a mental linking of part with part, and especially of the new with the old, so that the mind passes easily, and with content and satisfaction, from the familiar to the unfamiliar, and is able to inclose them all in one unitary movement of thought.

When, for example, do we feel that we understand the combustion of wood? It is apparently when we come to see in the process the union of three relatively simple elements—carbon and hydrogen, on the one hand, and oxygen, on the other. We think of these elements as acting in the form of imperceptible units (atoms), each of the first two kinds uniting separately with the third, one atom of carbon joining itself to two of oxygen and two of hydrogen to one of oxygen. We are able then to think of the units as being themselves unchanged in fundamental nature, or essence, but as changing their behavior because of their new situation or conditions; and this kind of change is quite in accord with our experience in the more familiar situations of common life. Men and animals, of course, act differently when brought into association with their fellows, and so also do objects which we regard as inanimate. A spool will roll down an incline if alone, but not if it is fastened side by side to another spool. So the needle of a compass points normally to the north, but it may be made (without contact) to point in any direction by bringing another magnetized object near to it. Even the heat of the combustion process finds in the motion concept something in the way of a familiar analogue, for small swiftly moving objects, such as flying sand, often give us sensations like those of heat.

Now, the notable thing about this process of mental organization and coherent system-making is that it is more than a convenient way of thinking our data, that is, holding a mass of facts in thought; it is, also, under the guiding principles which logic has discovered, *a means of reaching new facts.* The duly criticised demands of rationality (at least in the lower meanings of the term) as to what nature *should* be in outlying regions as yet unreached by experience are generally honored by her when experimental research subsequently follows the path marked out by deductive thought and opens up those (hitherto) unknown fields. For example, Newton held that a beam of white light was really a sheaf of rainbow colored rays, a sheaf which an interposed prism merely sorted out into its elements. He argued further that, if a second prism were interposed in the path of any one of the elementary, or spectrum, rays *after* their separation, no change in the color of that ray would be effected,—a rational expectation of his which was actually borne out in the experiments which he made with a second prism. This kind of (deductive) inference, based on the belief that nature is rational, is, of course, an integral part of all inductive inquiry in the larger sense of that term; and the significant thing is that, when duly guarded, it so generally works. The fact that it does work seems to involve a kind of accord, or correspondence, between the relations of things to each other as world objects and our own instinctive mental movements. Our minds are able often evidently to trace the course of nature's processes *in advance*,[4]—a capability in them which may probably be attributed to the fact that they have received so large a part of their training through contact with the natural world. To some extent the mind may be regarded as a phonograph upon which natural processes write their story (Hume's concept of mental habit), and which consequently in its after workings always has a tendency to repeat that story.

[4] Lord Bacon, however, condemned all attempts to "anticipate" nature.

It is apparently this correspondence of natural processes to our habitual and preferred ways of thinking to which we refer when we pronounce nature rational, or speak of the *thought* embodied in the universe. It is much the same thing as saying that the natural world is a comprehensible order, that is, can be understood. As we shall see, however, rationality often involves also the notion of approbation.

Different Kinds of Rationality.—In the first part of our study, under the head of scientific analogy, we saw that, *whenever possible*, interpretative ideas—those which serve to make facts rational or comprehensible—should be drawn from the same field as the phenomena to which they are applied; but we were obliged to recognize that this is not an inflexible rule, since it is not always possible. In some cases there are no such ideas, or none that are adequate. Indeed, in discussing the concept of energy, we found that, though it is used freely in physics, the idea is plainly drawn from the fields of physiology and psychology; that is, from our personal experience of effort and resistance. Corresponding to this difference of origin in our interpretative ideas—that is, varying according to the several fields from which they are drawn—there are three different meanings of the term, rationality of the world:

1. The universe may be regarded as rational when all its parts are susceptible of satisfactory arrangement in the mind by the use of ideas drawn from the domain of *physics*. Rationality then appears

to mean that the world is orderly—so fixed in its types of process that these can be completely described in natural laws and successfully predicted to the smallest detail. In this sense to call the world rational means much the same as to call it mechanical. It means that *the world is an adjusted, regularly working system,* characterized everywhere by invariable causal relations.

More particularly is rationality, when conceived thus under the analogies of physics, substantially identical with the principle of *the uniformity of nature,* which we have seen to be an essential element in the principle of mechanism. As was remarked on a preceding page,[5] the uniformity of nature is an implicit assumption in all scientific experiments. Without it science would be impossible, for then there would be no universality to knowledge.[6] If nature were not uniform in her activities, then what we observed to occur to-day might not, under precisely similar conditions, take place to-morrow. The lightning instead of being a spark of electricity, might to-morrow prove to be a flaming bolt of iron! Investigation of nature then would become a kind of perilous gambling. But science evidently *is* possible; its great achievements are the sufficient evidence of that possibility. It is plain, therefore, that there is *validity* (working value) to the postulate on which it rests—the uniformity of nature.

Yet even this consideration is not a *proof* of the *absolute* truth of the principle. Logically it remains a postulate still, though a postulate which has re-

[5] Cf. p. 143, *supra.* [6] Cf. p. 27, *supra.*

ceived so much confirmation [7] from experience that inquirers now regard it with all the confidence of an empirically discovered principle or law. We cannot really prove it, however; and this for two reasons; —(1) For one thing, the very tests which we apply to phenomena to prove their uniformity themselves assume the principle of uniformity. They assume, for example, that our senses—sight, touch, hearing —remain essentially the same from day to day, and that our standards of measurement—yard sticks, water grammes, etc.—are under identical conditions constant. But how are these underlying assumptions to be justified? One strives in vain to conceive some way of proving them which shall not itself in the very process assume them.

(2) The second reason is that dwelt upon by Hume, to the effect that all experiment, in the nature of the case, witnesses merely to the present or, when recalled in memory, to the past. It cannot point to the future without assuming this very principle of uniformity. "As to past *experience*," says Hume, "it can be allowed to give *direct* and *certain* information of those precise objects only, and that precise period of time, which fell under its cognizance: but why this experience should be extended to future times, and to other objects, which, for all we know, may be only in appearance similar; that is the main question on which I would insist."[8] Indeed, Hume's

[7] And so much suggestion, also, for how regular and predictable are the successions of day and night, of the moon's phases, of spring, summer, etc.!

[8] "Enquiry," etc., Sec. IV, Pt. 1.

query might be made more radical still; for how, without *assuming* uniformity, can we *know* that even when the objects are precisely similar, they will behave as we have observed them to behave in the past? There appears to be no answer to this question. We seem to be forced to content ourselves with the *assumption* that they will behave in the same way in the future. At bottom, therefore, uniformity is a postulate, a practical assumption adopted because it is needed.[9]

2. Rationality, in the sense just explained,—the principle of a worldwide interconnection of things in a way that is orderly from the point of view of ordinary physics—is all that the scientific postulate of rationality *necessarily* and unhesitatingly predicates, and all that some men of science seem to mean by the term. In the higher grades of existence, however, it seems clearly inadequate. It fails to meet all our requirements of a rational world. To say, for example, that the gastric juice exudes from the walls of the stomach, when food enters that organ, because the minute glands in which it is contained push it forth, and that these glands are themselves constricted by certain muscles, and the muscles aroused to action by certain nerves, is to give a useful explanation of this part of digestion, *so far as it goes*, but it is by *no means* to give *a full explanation*. Nor does it seem that such an inquiry into

[9] Cf. Professor Bain's remark as to this principle (Logic, Appendix D). "Without it we can do nothing; with it we can do anything. Our only error is in proposing to give any reason or justification of it, to treat it otherwise than as begged at the very outset."

causal antecedents, however far it may be carried, can ever content the mind. For a truly rational account of the functions of the stomach we need to know, also, what *end* the flow of the gastric juice serves—the *final* cause. The mind probably is never satisfied with any explanation of organized activity which does not reveal the *use* of that activity—the *value* there is in it.

In biology and psychology, therefore, not to speak of sociology and ethics, we instinctively resort to *a second meaning* of the term, rationality of the world. This is a *teleological* one, *the idea of such an adjustment of objects or parts to one another as is fitted to bring about some end* or ends. We are accustomed to pass judgment upon systems—engines, living things, institutions, etc.—according as they are, or are not, put together so as to effect the result in view. In so far as their features lack adjustment to the end of their existence, so far are they, and especially the features referred to, irrational. Thus the vestigial organs in the human frame, such as the troublesome vermiform appendix, are rational in the first sense of the word, since they are the results of orderly causal processes, and are entirely predictable; but, in so far as they now hinder the development of the organic type and interfere with its well-being, they are irrational in this second sense. An intelligent maker of such organisms, at least if he had only the production of successful organic types in view, would, if able, have eliminated these features ages ago. On the other hand, the many wonderful devices in the living organism for overcoming disease, destroying harmful bacteria, and restoring injured parts to health, are all eminently rational in the teleological sense. They all serve the one great end of maintaining the organism in vigor. It is evident that in this sense of the term there is a large amount of rationality in the world; things *are* adjusted to the realization of ends on a vast scale; but it is evident, also, that the rationality is far from complete. It is something to be expected, but also something for which at times we search in vain.

In this teleological or end-serving sense, also, rationality is, and it would seem must remain, a postulate, and that for both science and ethics. It cannot be proved, because of the fragmentariness of our knowledge. The indications point strongly to the conclusion that we know but a small part of the order of nature, our ignorance far surpassing our knowledge. The fact that we are able to understand part of the world is no *proof* that the larger part unknown to us would be intelligible, if our inquiries—with, let us say, ideal conditions—were pushed to the utmost limit of human capacity. On the contrary, it is quite possible that much of the unknown beyond is unknown just *because* it is *essentially* incomprehensible to human intelligence. On the other hand, *neither can the full rationality of the world be disproved*, though Herbert Spencer, Du Bois Reymond,[10] and the philosophical positivists have made strenuous attempts in that direction. The only conclusive

[10] A noted German physicist; his famous lecture on the "Limits of the Knowledge of Nature" is perhaps the strongest plea yet made in this direction.

proof as to the reach of human powers of knowledge is the final result of a vigorous and persistent use of them *to the end,* and that test will not be complete until the race is extinct!

In the meantime our opinions on this subject must remain matters of philosophic faith. We may properly enough *believe* with Leibniz [11] that the world throughout is soluble to reason of the human sort, and that a mind of the first order with adequate facilities would discern a sufficient reason why everything in the world is as it is and not otherwise, though this belief is less easy now than it was before the establishment of the doctrine of natural selection. On the other hand, we are free to believe, with Mr. Spencer, that, however comprehensible the world might be for a superhuman or divine intelligence, much of it is essentially and forever beyond the reach of even the highest *human* understanding. Finally, with the philosophical school of Schopenhauer,[12] we may hold that existence is essentially irrational, the intelligence of men and animals, and perhaps even the uniformity of natural processes, being but incidental and temporary phases in the endless life of a blind pulsating world Power or powers. This last view, which when first broached

[11] Leibniz (1646–1716) was a brilliant German mathematician and philosopher. He was the inventor of the calculus, and the author of an idealistic and strongly individualistic metaphysical system.

[12] Schopenhauer, Arthur (1788–1860), the fourth and last of the great idealists who succeeded Kant, departed from his predecessors by laying chief stress on the will, not the intellect. He is noted as the foremost occidental exponent of pessimism.

by Schopenhauer nearly a century ago was generally regarded as bizarre and absurd, has of late, in connection with the increasing prominence of the concept of energy, gained greatly in acceptability and vogue.

3. There is still *a third meaning* of the word, rationality. It is that of *conformable to valuable ends*, as these are estimated by our human experience of value. When in a court of law inquiry is made into the sanity of a man, it is not sufficient to show that he can reason to a conclusion, or use his limbs effectively for the promotion of ends chosen by him. He is not regarded as rational unless the conclusions which in all sincerity he reaches, and the things which with honest conviction he does, are such as are tolerable to society at large. If men in general are so averse to his conclusions and his acts that they cannot endure them, he is considered insane, or at least unsound in mind, that is, irrational. In this case it is not merely the presence of end-serving activity which is considered in determining rationality, but also, and *mainly, the nature of the end sought,* whether it is one to be approved; and the conception of rationality involved is derived, not from physics, nor yet from biology, but from the field of ethics and *conscious* life.

When we ask if the world is rational in this third sense, science can return only an agnostic answer; for it finds no clear evidence—certainly no proof—of general world adjustments to ends that satisfy the mind's demands as to value. Full many individual scientists *believe* that the world is thus rational, that it has a worthy conscious purpose directing it; but it is a matter of faith with them, and not a principle which can be established. There appears to be but one end of the world process that satisfies human thought, and that is the production of a high type of personality in conscious beings. But the individual development reached by the highest order of conscious beings known to us—mankind—and the satisfactions gained by man here in his brief, blundering, and suffering career, do not suffice to justify either the age-long preparatory stages nor full often the grievous ills of existence. The man who faces the facts of human life as a whole, with its sin and folly and woe, and who gets into sympathetic touch with the vast multitudes of the unfavored, or common, people, is very likely to become pessimistic, at least so long as he confines his outlook to the *present* life. Some degree of pessimism is thus one natural result of bringing the test of rationality in its highest form to bear upon our world, for the world certainly meets it but ill. The one end approved by reason is not attained by the vast majority, nor, the world being what it is, does one see how it can be.

Most men, of course, do not confine their view to the present life, but believe, rightly or wrongly, that human existence survives death, and continues on higher planes hereafter. The eminent philosopher Kant was one of these. Indeed, he maintained that the imperfection and fragmentariness of the present life was evidence that personal existence did not end at bodily death. He felt that the world must be teleologically rational—organized so as in some way to meet the demands of our highest natures—and that consequently a future life for the vindication of that rationality was an inevitable conclusion.[13] At this point we come to the confines of religion, which is a field lying beyond the scope of this book. Yet it is proper to add that one who believes in immortality is able also to believe that the world is rational in this third and highest sense; for he is able to look upon all human infirmity on earth as but an intermediate and preparatory stage in the individual's long development toward the ideal, and upon the woes of the present life as but the means whereby a future higher and happier personality is being brought into existence, in fact as the birth pangs of a worthier type of man.

Exercises

1. Give five examples in which the uniformity of nature is postulated by men in practical life.
2. State five concrete cases in which it is postulated by men of science.
3. Describe five or more natural processes which indicate adaptation of means to an end—regardless of whether the end is good and sufficient.
4. State two cases of seeming irrationality in nature because of uselessness of parts or of hindrance to the realization of what seems to be the natural end.
5. Show how the assassins of Pres. Garfield and the would-be

[13] Cf. "Crit. of the Prac. Reason," II, chap. II, sec. 4. Kant, Immanuel (1724–1804), was a professor at the University of Königsberg, Prussia, for over thirty years. He founded the critical school of philosophy, and by many is regarded as the greatest philosopher since Aristotle.

assassin of ex-Pres. Roosevelt were rational in the first two senses of the term but not in the third sense.

6. From what point of view—that is, on what political postulates—might the assassins of Presidents Lincoln and McKinley be held to be rational in all three senses?

7. Make a careful summary of Kant's argument for immortality on the assumption of the full rationality of the world. ("Practical Reason," chap. II to sec. 4.)

8. Do the same with John Fiske's "Destiny of Man," pp. 96–119.

9. Do the same with Smyth's "Through Science to Faith," chap. XII.

CHAPTER XIII

THE EXTERNAL WORLD

Postulate of External Actuality.—Another major postulate of physical science is the *actuality of the external world.* Science joins with common life in assuming for practical purposes that the physical objects with which it deals—stars, waters, minerals, etc.—have some sort of existence in themselves, apart from man's thinking about them. It does not pretend to *know* what, for example, a piece of iron is in itself, still less to account for its absolute origination, if such a thing ever occurred; but it proceeds on the working assumption that the iron is as truly an existence, with established forms of behavior, as is the individual that studies it and uses it. The student should carefully distinguish this *postulate,* which perhaps seems to him a mere useless truism, from any *metaphysical* affirmation as to the nature of physical objects. Science does not teach that so-called external objects are really external to the mind. Such a teaching would be philosophical, not scientific, for it cannot be experimentally verified. It would be metaphysical *realism.* Science simply affirms that *we can treat those objects as though they had a more or less independent existence of their own* [1] and in so

[1] Cf. Whetham, "Recent Develop. of Phys. Science," p. 44: "While natural science is not committed to any particular philosophical system . . . the language it uses habitually is based on the

treating them we will not be brought to confusion, but will be able to use them for the purposes of thought and life.

Involved in this working assumption is the like postulate of the objective actuality of space and time. As we have seen, all material things have extension, which means that they exist in space. If they are to be treated as objectively actual, space likewise must be treated as actual. So, also, as to time. Every *event* takes place in time; and if the objects concerned in these events, together with their behavior, are to be treated as actual, there seems to be no reason for treating otherwise the time periods in which the behavior occurs.

When we pass, however, from the domain of science to that of philosophy, we find external actuality by no means universally conceded. It is anything but a truism in metaphysics. From the time of the English philosopher, Berkeley,[2] nearly two hundred years ago, it has been a disputed question whether there is any actual external world, that is, any existences that are non-physical, unthinking, and unfeeling. Nor is this question a mere cavil, a trifling, negligible objection raised against received opinion. It has been seriously answered in the negative by men of large ability.

common sense realism, which is the philosophical creed of most men of science. . . . But science talks of matter and energy as though it knew of the existence of realities corresponding with the mental images," etc.

[2] Berkeley, George (1685–1753), was an Irish prelate of the Anglican church. He is the foremost representative of subjective idealism.

It was urged by Berkeley himself with utmost zeal and conviction that all existence is spiritual, and that the whole notion of non-spiritual existence is illogical and illegitimate. "It is evident," he says, "to any one who takes a survey of the *objects* of human knowledge that they are either ideas actually imprinted on the senses; or else such as are perceived by attending to the passions and operations of the mind; or, lastly, ideas formed by help of memory and imagination . . . As several of these are observed to accompany each other, they come to be marked by one name, and so to be reputed as one thing. Thus, for example, a certain color, taste, smell, figure, and consistence having been observed to go together are accounted one distinct thing, signified by the name apple." [3] A physical object is thus for Berkeley an established, or recurrent, *cluster of sensations*. "That neither our thoughts," he adds, "nor passions, nor ideas formed by the imagination, exist without the mind, is what every body will allow. And it seems no less evident that the various sensations or ideas imprinted on the sense, however blended or combined together (that is, whatever objects they compose) cannot exist otherwise than in a mind perceiving them . . . As to what is said of the absolute existence of unthinking things without any relation to their being perceived, that seems perfectly unintelligible. Their *esse* is *percipi* . . . . What do

[3] "Principles of Hu. Knowledge," ¶I. The reader of Berkeley should constantly bear in mind that for him "idea" always means some kind of image, either of sense or of imagination, and not a concept, or notion.

we perceive besides our own ideas or sensations? and is it not plainly repugnant that any one of these, or any combination of them, should exist unperceived? [4]

The outcome of Berkeley's argument is that the physical world is entirely ideal, that is, constructed of ideas (images), the constructor being either the mind which knows them, as in the play of imagination, or that mind in connection with some other mind, as in human intercourse. Only mind (spirit) is truly real, an existence in itself. Material objects are "collections of ideas," and ideas are always and necessarily the product of mind. They are as distinctly and entirely the *results* of the mind's activity as are the pictures of a magic lantern or kinetoscope the results of the machine's activity. Of course, ideas can be shared by two or more minds; that is, one mind may lead another mind to think similar thoughts. This is supremely true in the case of God and man. God's fixed thoughts are what we call the objects of nature; and knowledge of natural objects (ordinary sense perception) really consists in coming into contact with the mind of God and sharing his thoughts, though these being orderly, permanent, and universal, we too often do not recognize them *as thoughts*. This theory of Berkeley is the core of the type of modern philosophy known as *idealism*,[5] though most idealists now differ with him as to the conception of God.

Berkeley's argument rests on an assumption which

[4] *Id.*, ¶¶ 3, 4.

[5] Cf. Royce's "Spirit of Mod. Philos.," lec. XI, for an excellent example of this type of thinking.

it never occurred to him to question, an assumption which was the common presupposition[6] of the reflective thought of his time. This was the conception that all knowledge is an awareness of our own ideas, or images. This view, no doubt, seemed necessitated to many by the fact that the mind appeared to be mysteriously hid below the surface of the body (in the brain) and never to come into actual contact with external objects. Whatever object came before it must therefore be *within* the body, that is, must be either a sensory or a reproductive *image.* This view was naturally reënforced by the familiar perception errors, which seemed to indicate that the mind in perception was not dealing with actual objects, but with representations, or images, of them. This consideration impressed Hume deeply. "The slightest philosophy," he says, "teaches us that nothing can ever be presented to the mind but an image or perception, and that the senses are only the inlets through which these images are conveyed, without being able to produce any immediate intercourse between the mind and the object. The table which we see seems to diminish as we remove farther from it: but the real table, which exists independently of us, suffers no alteration; it was therefore nothing but an image which was present to the mind. These are the obvious dictates of reason; and no man who reflects ever doubted that the existences which we

[6] A presupposition is an assumption or postulate which is accepted on the authority of prior inquiries. Often presuppositions are the established empirical principles of a more elementary science. Thus, the laws of physics are presuppositions for biology.

consider when we say, *this house* and *that tree*, are nothing but the perceptions in the mind, and fleeting copies or representations of other existences, which remain uniform and independent."[7] It will be observed that Hume concurs with Berkeley's arguments,[8] but does not reach Berkeley's conclusion. On the contrary, he assumes that there are real, nonpsychic existences, though we never perceive them.

This is a very serious argument, and one that will bear much reflection. There is a difficulty in it, however. If "nothing but an image" is ever "present to the mind," how can we possibly know that beyond the images, and represented by them, there are "other existences, which remain uniform and independent?" Hume confesses this difficulty on the next page. "Here," he says, "experience is, and must be, entirely silent. The mind has never anything present to it but the perceptions, and cannot possibly reach any experience of their connection with objects. The supposition of such a connection is therefore without any foundation in reasoning." He concludes that at this point "the profounder and more philosophical skeptics will always triumph;" that is, will show that belief in the external world is rationally unfounded. For himself Hume takes refuge in what he calls a "*mitigated* or *academical* skepticism," which bids us, on the one hand, confess that theoretically we do not know that any physical external world exists, but, on the other, acts as practical

[7] "Enquiry," etc., Sec. XII, Pt. 1.

[8] As to these his judgment is "that they admit of no answer and produce no conviction."

beings on the common sense postulate of its actual presence. The skepticism of this conclusion, however, is not very "mitigated" as regards the needs of thought. It leaves the mind a house divided against itself.

Descartes, also felt the force of the critical objections to the objectivity of our knowledge, and rested his confidence in the actuality of the physical world, and the essentially true representation of it in clear and distinct ideas, on his faith in God. He first established, as he believed, the existence of God by considerations drawn from the nature of his own consciousness and its ideas, and then argued that our bodies, the earth, and the stars, and the like, are all to be accounted actual, and our ideas of them, so far as these are clear and distinct, to be considered true, on the ground that the perfect Being to whom we owe everything would not put us in hopeless subjection to error.[9] Hume refers to this way out as an "unexpected circuit," and certainly it has not proved a way passable for most minds. Descartes' arguments for the existence of God are generally accounted very inconclusive. Nor does it appear that the veracity of the Deity is involved in the truth of clear ideas, since it is not essential to human welfare that we should have a knowledge of the actual existence and nature of the physical world. Berkeley, for

[9] "Method," Pt. IV. It should be added that Descartes looked upon ordinary sense qualities as confused ideas. It was only the quantitative representation of the external world—in terms of number and arrangement—that he held to be clear and distinct, and therefore divinely guaranteed.

example, lived a useful and happy life in entire disbelief in its existence.

The Scotch school of realists took another path. They maintained the actuality of the external world on the ground that every peripheral sensation is a trustworthy *sign* of a corresponding physical object. When challenged for the proof of this, the representatives of this school[10] replied that common sense made it evident. Everything, and especially everything that the mind perceives clearly and distinctly, must have a cause, and this cause in the case of perceptions must be a corresponding outer object. But Berkeley, as much as Reid, believed that perceptions are causally produced, and their cause he believed he had found in experience, namely mind, or spirit. We know that some ideas are mind-made; in the absence of knowledge to the contrary it is reasonable to hold, he maintained, that all ideas are so made.

For the Scotch school to maintain, on the contrary, that the cause of the ideas must be just what the ordinary man supposes—some external unperceived and unproved object—is not reasoning, but at best over-emphasized theorizing. It is what Kant called dogmatism, a mere insistence upon common opinion.

Are we then, if we would avoid philosophical skepticism, shut up to the subjective idealist view that objects of sense are merely more or less permanent clusters of sensations, and entirely mind-made? So

[10] Reid and his successors. Thomas Reid (1710–1796), was the chief founder of the Scottish "common-sense" school of philosophy. He was professor of moral philosophy at Glasgow.

it has seemed to many philosophers from Berkeley's day to our own. For some time past, however, an antagonistic, quasi-realistic influence has been gathering head within the pale of science. Science, indeed, has taken no direct part in this dispute. As we have seen, it has contented itself with *postulating*, not strictly assuming, the more or less independent existence of the physical world. The term *phenomenon*, so common in its discussioons, reveals its logical position. The word means *something that appears*, and an appearance manifestly may be an existence in itself or the representation of an existence beyond itself or the pure creation of the mind. Among these possible meanings science makes no choice. Nevertheless, science has had so much success in investigating "phenomena;" it has found so many hitherto unknown, and has framed from them such an extensive edifice of valid laws and successful agencies of control; that is, its postulate of actuality has worked so well, has been borne out so well by results, that ordinarily it forgets that it is working on a postulate, and tacitly regards the "phenomena" as either objective existences or functions thereof. To put the situation in another way, the fixed, mentally uncontrollable, objective, part of knowledge—facts and laws—has increased enormously within the past two centuries; so that now the man of science has a strong sense of an established order of things beyond himself, a sense that is not satisfied by the metaphysical explanation that it is all a mere mental construction from top to bottom, facts not excepted. If the world order is mental, it is at least an *order*, and a very objective one, one making substantially identical demands upon all inquirers.

Another, and an important, realistic factor in present-day metaphysical thought is the new prominence which science has given to energy, and its location of it within the objects which manifest it. Things that work changes do not seem to be *mere* appearances, but rather to have much the same sort of claim to the rank of existences in their own right that we have ourselves. The influence of this realistic drift within the confines of science has been felt by philosophy in two ways: (1) Most thinkers of the general school of Berkeley now call themselves *objective* idealists. They concede the objective reality of material things, while still maintaining that the essence of those things is psychic. (2) Others, being strongly impressed with the value of the methods of the physical sciences, have examined afresh and with greater rigor, the traditional teaching that perception must be primarily an awareness of images within the organism. It has always been usual to think of perception in terms of visual or tactual processes, and to conceive of consciousness as *immediate* vision or touch of the object by the mind. This evidently implies that the mind is an inner observer, apparently occupying space, within, say, the brain, an observer able to see and feel an object if it comes close enough. From this point of view Hume's argument drawn from the table's changefulness of aspect, is perfectly conclusive. We cannot believe that the actual table transforms itself in such Protean ways, according as we move toward it or away from it, or that for a hundred observers it has as many different shapes. What the mind perceives in that case must be a mere image formed within the body by the mechanism of eye, optic nerve, and so forth.

But why should we think of perception on the basis of such an artificial hypothesis? There is nothing to indicate that the mind is a kind of sprite or kobold located in the dark somewhere under the skull; nor will all perception bear description in terms of such picture viewing or surface feeling. When we listen to an oration, to music, or to the roar of a torrent, we do not think of the sounds as being objects which confront us, nor yet as images of such objects. Neither do they bear any likeness to tactual images—such, for example, as we may gain by the pressure of our fingers upon the violin strings or the speeding water. We may indeed *associate* visualized objects with the sounds, but that is only when we know something of the *causes* of the sounds from other sources. The like may be said of the senses of smell and taste and temperature.

Suppose that instead of conceiving of perception as the immediate vision of an object, or as a kind of tactual awareness of it, by an inner self confined in some recess of the body—suppose we think of it as merely the setting up of dynamic relations between our organisms and other existences, these relations varying in character according to the sense involved. The interconnections between a bell and the cortex of the brain will, of course, be different when we *see* the bell in sufficient light from what they are when we *hear* it, or lay our hands upon it, at night. Be the character of these relations—the processes of stimulus and reaction—what they may, they may all of them be accounted parts of the perception process, *provided* they enable us to *appreciate* the object—that is, to get suitably varied and modified feelings of pleasure and pain through our connection with it—and also enable us to *react to it successfully*. When perception is regarded in this way, the whole difficulty as to the possibility of knowing external objects seems to disappear. That cognitive relations should be modified by change of position on the part of our bodies is in accord with all our knowledge of relations,—for example, the dynamic relation which we call gravitation, which increases inversely with the square of the distance. On this view the so-called mental "images" —really perceptions—which psychology deals with become *effects* in our central nervous system, made (in the last analysis) by processes entering the organism from without. They are not intermediate stages of the process of knowledge but the final stage, not things known but the knowledge itself, not objective but subjective.[11]

[11] The image formed on the retina of the eye in visual perception is, of course, an intermediate stage in the knowing process, but it is a purely mechanical one. It is itself never an object of sensory consciousness, and certainly is not the image the mind is said to perceive. The proof of this statement is the fact that when there are certain lesions in either the optic nerve or the occipital lobe of the brain, there is no vision, even though the eye and the retinal image be perfect, and the person otherwise in normal condition, physical and mental. The relation of the retinal image to perception seems to be analogous to that of the cameral image in photography to the picture afterward developed on the plate. In neither case does the final result know the intervening image which was a part of the process by which it was produced.

It may be urged that this realistic account of perception is no genuine account of perception at all; that, in fact, it omits the very heart and mystery of the process. There is no doubt truth in this objection on the psychological side. The description is highly schematic and vague; it leaves large and important gaps for the psychologist to fill in. On the logical side, however, the realist is able to urge that his description includes the two chief functions of consciousness, satisfaction and successful reaction, and what more (if as much as that) is included in the notion of seeing or touching something in the brain?

Now, if the hypothesis of brain sight or brain touch be given up, there seems to be no longer any reason,—aside from cases of introspection—for regarding the objects of perception as sensory images, or purely psychical phenomena. If to be in a certain kind of dynamic relation or mediate continuity with an object, that is, connected with it by proper continuous impulsive processes—if this constitutes perception, then the object may be a wish (purely private and psychic), a cramp in a muscle (private but physical), a tree on the lawn (physical and external), or a star in a remote constellation, and the relational connection, or rather the final stage of it, will in each case be perception or awareness. The location of the object is never *explicitly* given in the sensory foundation of any perception, though there are certain features, or "signs", in the underlying sensations, such as contrasts, relative positions, efforts, durations, and so forth, in which location is generally given *implicitly;* that is, a critical comparison of these with the "local signs" in other experiences enables the percipient to determine the location of the object with reasonable success.

It appears then to be perfectly possible to answer the question as to the actuality of the external world in the affirmative, though it may not be possible to offer any argument that will convince the subjective idealist of the truth of that answer. For example, the very pertinent fact that, irrespective of their wishes regarding it, different observers agree substantially in their descriptions of a given "external" object, is not considered proof of externality by the subjective idealist. He finds an explanation of it in the likeness of nature and conditions in the different observers. One may take either side of this question; but the fact that the *postulate* of actuality has *worked* so well, and served as the basis of so much progress in knowledge, will doubtless lead an increasing proportion of thinkers to adopt some realistic view.

Relativity of Knowledge.—Granting the actuality of the outer world, a further question, and one of much greater age, remains: *Can we know that world as it actually is in itself?* Incidentally this question has received some discussion in these pages already; for we have seen how Hume reached the essentially skeptical position that in deference to common sense we must believe in a world beyond the mind, though reason affirms that we have no adequate ground for so doing. Kant, who was the next great critical philosopher, limited the authority of common sense more rigorously. Something, he maintained, must exist apart from ourselves in order to make upon us the manifold impressions (perceptions) of which we are aware, but *in the nature of the case* that something—the "thing in itself"—is entirely different from our thought of it, and is essentially unknowable. This must be so, he held, because there are evidently unconscious processes in the mind—forms of instinctive and purely mechanical mental activity—which work over and modify the material (stimuli) that comes into the mind from without *before* we are aware of that material. That is, when we perceive an object it has already been transformed by the unconscious mechanism of the mind, and is what the mind has made it, not what the "thing in itself" actually is. The object perceived is doubtless as different from the "thing in itself" as a costly vase is from the lump of clay from which it was formed; probably it is far more different. This is virtually the conclusion to which Protagoras and his fellow Sophists came in the fifth century B. C., and is a radical statement of the philosophical principle known as the *relativity of knowledge*, the principle that the mind itself contributes essential and, indeed, transforming elements to the objects which it knows. In this extreme form, however, it has never received universal acceptance among philosophers, though for a century after Kant its vogue was immense.

Primary and Secondary Properties.—Both in ancient and modern times philosophy, in the persons of its greater representatives, has generally adopted a less extreme view, and sanctioned a distinction which is now associated with the name of John Locke,[12] the distinction between the *primary and secondary properties of things*. In knowing the primary qualities of objects it is held—and physical science tacitly accepts this view—we know things as they actually are in themselves, whereas in knowing their secondary qualities we merely know *their effects upon us*, and in these respects our knowledge of them is purely relative. Now, the *primary properties* of things are those which have been *conceived* rather than perceived by the mind, properties which on a critical view of experience it concludes *must* characterize things in themselves; that is, they are of a logical rather than a sensory character. They are of two kinds: the mathematical properties of number and extension (including figure) and the dynamic properties of resistance (impenetrability) and impulsiveness (elasticity, chemical affinity, and whatever issues in motion). These two groups are the properties with which physical science is chiefly concerned. The ordinary sensory qualities of things, such as color, sound, odor, flavor, warmth, etc., Locke called *secondary*, holding that these are most reasonably to be regarded as *results*—effects of a combination of the activities of the object itself (the stimulus) and the reaction of our organisms.

This is a distinction of large *practical* value, as is evident from the fact that science makes use of it, though its theoretical validity has been sharply dis-

[12] John Locke (1632–1704) was a noted English philosopher of large ability. His originality is disputed, but of his great influence on subsequent thought there can be no question.

puted. With our present knowledge of the mechanism of sensation we cannot conceive of the secondary qualities as existing without *other factors than the activity of the object itself*, factors such as ether waves, air waves, and above all a highly complex percipient organism. However green the grass ordinarily, it is apt to be golden in the afternoon light, while it has no color at all at night. A cloudless sky is likely to be blue, but it may also, as in the west just after sundown, present a spectrum of hues ending in darkest red. Nor is the ringing of a bell the sole cause of the sound we hear. Without the concurrent agency of the atmosphere, there would be no sound, as may easily be proved by ringing the bell in a vacuum. Furthermore, we cannot conceive of all the bells on earth, though all rocked at once by an earthquake, as making any real *sound*, if there were no ears to be reached by the air waves they set moving. It thus appears that sensory knowledge, constituted as it is of secondary qualities, is never a copy or reproduction of the situation in any external object by itself alone. *It is an inner mental product due to the action of the object and coöperating agencies upon the organism and the reaction of the central nervous system thereto.*

None the less the secondary properties may evidently for practical purposes be treated as belonging to the object itself, for there must be in it some specific arrangement, or organization, of dynamic units (molecules, etc.) which is their indispensable condition or (partial) cause. The question as to their true *theoretical locus* is in dispute. For the naïve realist the *property of an object* is properly something *in it,* some essential part of its own nature or structure, a characteristic which should be carefully distinguished from the *sensation* which that property causes in us. The whiteness of snow, he insists is a permanent situation or arrangement in the snow itself, a matter of geometrical and dynamic structure, and by no means the same thing as the effect which that situation produces in us, an effect which should be called, not whiteness, but the *sensation of* whiteness. On this (realistic) view the distinction between primary and secondary qualities becomes a relative one, the former being simply those properties which we find ourselves obliged to attribute to *all* material things, and the latter those special types of the primary qualities the presence of which distinguishes one substance from another. *Both* kinds of property are essentially logical rather than empirical.

On the other hand, the objective idealist, while conceding that snow is white for practical purposes, since in the mass it always has a characteristic arrangement of its crystalline particles which, in ordinary light, causes in a normal human percipient the sensation of white, yet contends that whiteness as *such* is, strictly speaking, not a situation, but a temporary phenomenon, an *event,* and one *which takes place in the organism, and nowhere else.* It is there that the dynamic situation arises which yields the secondary property of whiteness. This contention he supports, not only by the unquestioned fact that ordinary light and a normal percipient organism *are* necessary for its existence, but also by the further fact that the whiteness diminishes in degree, and finally vanishes, as inspection of the snow becomes more minute, as, for example, under the microscope. That is, snow is not white when the inspection is so close as to eliminate the influence of the combined refractions of many crystalline surfaces; on the contrary, it has as little color as ice or glass. It is evident that this dispute is essentially one as to the best *use* of the term property. It is probably not very important which usage is adopted; but it would be a distinct gain for philosophy if one of the two could gain general acceptance, and so ambiguity and needless discussion be avoided.

Reference has been made to the fact that the distinction between primary and secondary qualities has been challenged on the theoretical side. It has been urged repeatedly, from Berkeley's time to the present, that the primary qualities, also, are mere effects made upon us by agents which themselves are never given in experience. There is ground for this claim in the somewhat uncritical fashion in which primary qualities have often been enumerated. Locke, for example, counts solidity among the primary qualities, and describes it in such a way as to suggest that what he means is the sense of resistance we have in encountering material objects, which is, of course a sensory or secondary property. What he had in mind, however, was probably, not the feeling of resistance, but the abstract notion of impenetrability, or exclusive occupancy of space, which is not an impression of sense but a product of thought. Properly stated, the *primary* qualities of objects represent the efforts, and apparently so far as they go the successful efforts, of science to ascertain by *mental construction* the character of things in themselves; that is, to eliminate from our perceptions the elements due to the reactions of our organisms, and then to separate in thought the activities of the objects themselves from the concurrent agency of media, and so forth. They are not direct percepts, still less mere sensations, but are the logical results of working over analytically and synthetically in selective comparisons a large number of perceptions. For example, awareness of things in number relations—as one, two, three, etc.—involves critical comparison of and abstraction from various experiences. Similarly extension, motion, and energy are properties attributed to objects by reflective thought after a critical comparison of many sensory experiences.

It may still be urged, however, that the most thoroughly criticized primary properties are still mere relative knowledge, because with all of reflective thought's comparing and analyzing and abstracting, it never has anything but sensory experience, that is, relative knowledge, as its *material*. and cannot possibly transcend that and reach something essentially different, that is, those ultimate causes of experience which themselves are never present in experience. This is searching criticism; yet it rests upon an assumption, and an assumption which appears to be needless. It is the assumption that the external causes of our experience *are* essentially different from *all* our experience, *including our experience of our-*

selves. But why make such an assumption? It seems far more probable that man is a child of nature, and consequently more or less akin to all other natural objects. If, as is likely, both man and the substantial objects of his knowledge are dynamic and impulsive in essence, it does not appear why he may not succeed in at least partially comprehending and appreciating those objects as they are in themselves by using his immediate acquaintance with himself as a means of interpretation.

Primary Qualities not the Sum Total of the External World.—On the other hand, it is an evident case of the fallacy of simplification[13] to assume, as is not infrequently done, that a complete statement of the primary qualities of things would be a *full* description of the external world.[14] Those qualities are all of them constructs from effects produced in our organisms by external agencies, and there is not the least reason to suppose that, directly or indirectly,[15] our organisms are sensitive to all that goes on in the natural world. Indeed, analogy from such shortcomings as our lack of an electrical sense would lead us to think the very contrary. Existence beyond ourselves may well be far more various and rich than the present scientific descriptions of things would lead us to think;[16] in

[13] Cf. p. 149, *supra*. [14] Cf. Whetham, o. c., p. 11.

[15] An example of indirect susceptibility to natural processes is that of the accumulation of effects of exceedingly weak or ultra light waves, which are themselves imperceptible, upon a photographic plate, where their combined effect at length becomes perceptible to the eye.

[16] Cf. the remark which Shakspere puts in the mouth of Hamlet: "There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy."

fact it must be so if our human nature in all its phases is to be traced back to the activities of the natural world. In this conclusion, with its wide possibilities of other existences and stages of being, critical theology finds its field of inquiry and faith.

> "But beyond the bright search-lights of science,
> Out of sight of the windows of sense,
> Old riddles still bid us defiance,
> Old questions of Why and of Whence.
> There fail all sure means of trial,
> There end all the pathways we've trod,
> Where man, by belief or denial,
> Is weaving the purpose of God."
>
> Whetham, o. c., p. 10

Exercises

1. Describe the mechanism of perception of one of the senses (Cf., for example, the account of vision or hearing in a good encyclopædia or physics text-book, or Tyndall "On Sound," pp. 73 f, 77 f). Show what the external cause of the color or sound must be and how it differs from the sensation (color, sound, etc.), itself as we experience it, and bring out the distinction in this case between the primary and the secondary properties.

2. Summarize as cogently as you can Hume's argument to prove that philosophical skepticism as to the senses is invincible. (Cf. "Enquiry," etc., sec. 12, Pt. I.)

3. Make a careful synopsis of the arguments by which Berkeley ("Prins. of Hum. Knowl.," ¶¶ 1–41) seeks to prove that only spirits exist in their own right, all the objects of sense being merely the spirit's "ideas."

4. Do the same with Royce's argument to the same effect in his "Spirit of Modern Philosophy," Lec. XI.

5. Outline carefully the line of thought by which Descartes comes to a realistic conclusion in his "Discourse on Method," Pt. IV.

6. State in detail the main points of Huxley's discussion of the problem of knowledge of existences independent of your thought of them in his essay on "On Sensation," etc. (Cf. "Pop. Science Monthly," IV, p. 86 f, or "19th Century," V, p. 97 ff.)

7. Give Huxley's reasons for holding that Descartes' teachings contained the germs of both idealism and materialistic realism. (Cf. "Method and Results," essay IV.)

8. Summarize chapter VII of J. A. Thomson's "Introduction to Science."

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