The Character of Natural Philosophy

by Richard J. Connell

A. The Issue

THOSE WHO DWELL in Academe know that the origins of science and philosophy are the same, both disciplines having started with Thales, the Greek theoretician who attempted to account for natural entities by hypothesizing, Aristotle tells us, that they were produced out of water through variations in the latter's density. Speaking roughly, one can say that because Thales' speculations embraced the whole of nature, and because he attempted to understand things through first principles, Academicians look upon him as the founder of philosophy. On the other hand, because his speculations explained natural things in terms of a material constituent (he proposed the first theory of matter) Academicians look upon him as the first scientist. And what can be said of Thales can also be said of the other pre-Socratic philosophers, for as a group they are regarded by historians as both scientists and philosophers. The Greeks themselves used the names " science " and " philosophy " synonymously, a convention that was still observed at the time of Kepler and Newton. Even as late as the nineteenth century Claude Bernard spoke about the characteristics of " experimental philosophy." This is hardly news, however, so let me come to the point: if for centuries " science " and " philosophy " were synonymous terms, how at a later date did they come to stand for different disciplines in Academe? What set them apart? This often discussed question seems worthy of further pursuit, for it appears to me that a precise, formal understanding of what brought about the divorce between science and philsophy is necessary if one is to determine their separate functions in the academic environment.

Many, of course, have written about the scientific revolution that dates from Copernicus, yet, as I said, I wish to look at it anew; for despite the many scholarly accounts of this historical event, it is my conviction that the central issue has not been clearly formulated. Therefore let me restate the problem in the following way: what, precisely, brought about the divorce of two disciplines that were originally one?

To be sure, the general answer to the question that looks for the grounds of the divorce between philosophy and science is well known and can be accurately stated in a single line: ". . . the modern quantitative and descriptive approach to terrestrial motion is very different from the qualitative approach of Aristotle, . . ."[1] This short quotation expresses the substance of the modern view, according to which the introduction of quantitative procedures into the systematic study of motion initiated the separation of science from philosophy. Natural science became quantitative and mathematical; philosophy did not. Yet measurements and mathematics had been employed in the study of astronomy, as well as other disciplines, for centuries; and so in a sense there was nothing that was new. The question, then, should be put more narrowly: why did physics (which opened the door for the other sciences) become irrevocably quantitative and mathematical in character in the period from Copernicus to Newton? Once this is known, the principal question to which this essay is addressed can be answered, namely, what is the character of natural philosophy?

At this point the reader may be thinking that the preceding paragraphs introduce the question about what natural philosophy is in perhaps an unnecessarily elementary way. He may wonder why there is no statement saying that my aim is to justify and describe natural philosophy with a view to showing

[1] This quotation (from Holton and Roller) is very plainly representative of the common view. Cf. Holton, G. J.. and Roller. D. H., ***Foundations of Modern Physical Science*** (Reading, Mass., 1958), p. 22.

it to be a legitimately distinct discipline. Yet he will surely realize that another discussion of natural philosophy will not be of much interest if, repeating what others have already said, it starts with a historical examination of the various positions philosophers can take on whether there is such a thing and if so what it is.[2] The present way of introducing the issue has the advantage of raising a clearly defined problem which is resolved only by showing (1) that there must be a natural philosophy, and (2) a little about what it is. Going about the matter this way has the additional advantage of showing more readily the relation natural philosophy has, not only to the natural sciences, but to the philosophy of science as well, which means that one ends with a more complete understanding of the various parts of the academic enterprise that bear directly or indirectly on nature. Briefly, then, I shall argue that the character of the natural sciences as quantitative and mathematical, instead of supplanting a "qualitative" consideration of nature, makes obligatory a separate, albeit restricted, discipline that is appropriately called a philosophy of nature.

This is not to say that at the close of this analysis everything will have been done. On the contrary, many points must unavoidably go undiscussed. If, however, the main thesis has been made clear, additional considerations can be made at a later date. With these points in mind, then, let us now approach the issue.

Opinions on the Copernican revolution, everyone knows, have been many and they are summarily represented as to type by Alexander Koyré in a passage it will be useful to quote:

> . . . This revolution has been described and explained—much more explained than described—in quite a number of ways. Some people stress the role of experience and experiment in the new science, the fight against bookish learning, the new belief of modern man in himself, in his ability to discover truth by his own powers, by exercising his senses

[2] I recommend that the reader see Ernan McMullin, "Philosophies of Nature," this journal, Vol. 43, No. 1 (Winter, 1969).

and his intelligence, so forcefully expressed by Bacon and Descartes, in contradistinction to the formerly prevailing belief in the supreme and overwhelming value of tradition and consecrated authority.

Some others stress the practical attitude of modern man, who runs away from the *vita contemplativa,* in which the medieval and antique mind allegedly saw the very acme of human life, to the *vita activa*: who therefore is no longer able to content himself with pure speculation and theory; and who wants a knowledge that can be put to use: a *scientia activa, operativa,* as Bacon called it, or, as Descartes has said, a science that would make man master and possessor of nature.

The new science, we are told sometimes, is the science of the craftsman and the engineer, of the working, enterprising, and calculating tradesman, in fact, the science of the rising bourgeois classes of modern society.[3]

Considering them commonly, such accounts of the scientific revolution are, it would seem, accidental in the sense that they regard the theoretical mind as being shaped by intellectual and affective attitudes that are extrinsic to the content of the issues themselves; in other words, they represent the mind as distracted by non-essentials. If one divides the accounts into types, he can say that some of them are worldly in the sense that they assume practical advantages to be the determining historical factors initiating the scientific revolution, which implies that the theoretical mind had sold its talents for worldly benefits. To be sure, one can hardly deny that the technology accompanying the scientific revolution accelerated the development of the modern commercial era and gave men an extensive dominion over nature; but the question is, did the development of industrial manufacturing bring about the quantification and mathematization of the study of nature?

But Koyré offers another explanation, one that he endorses himself:

. . . I am convinced that the rise and growth of experimental science is not the source but, on the contrary, the result of the new theoretical,

[3] Alexander Koyre, *Newtonian Studies* (Cambridge, Mass., 1965), pp. 5-6.

that is, the new *metaphysical* approach to nature that forms the content of the scientific revolution of the seventeenth century, a content which we have to understand before we can attempt an explanation (whatever this may be) of its historical occurrence.

I shall therefore characterize this revolution by two closely connected and even complementary features: (a) the destruction of the cosmos, and therefore the disappearance from science—at least in principle, if not always in fact—of all considerations based on this concept, and (b) the geometrization of space, that is the substitution of the homogeneous and abstract—however now considered as real—dimension space of the Euclidean geometry for the concrete and differentiated place-continuum of pre-Galilean physics and astronomy.

As a matter of fact, this characterization is very nearly equivalent to the mathematization (geometrization) of science.[4]

In substance Koyré maintains that the scientific revolution came about as the result of a new metaphysics, a metaphysics that regarded the universe as fundamentally mathematical in nature, a metaphysics that in Kantian fashion looked at the world a priori, demanding of nature answers to questions that the mind imposed upon nature from its a priori, mathematical preconceptions. Koyré argues that with modern science Pythagoras has returned, and henceforth God is to be viewed as a mathematician. One might add that whatever the merits of this explanation, it is not likely to be regarded as worldly.

It appears to me, however, that, whether or not the modern mind views the universe as at bottom a set of mathematical entities, such a mathematical view does not account for the quantification of physics. In that respect this metaphysical position does not seem correct, and a better answer can be given to the question. One may argue, that the true foundation for the modern revolution is to be found in the philosophical position contained in Newton's laws of motion. And they supply a reason why physics became mathematical that is very simple; but unhappily its simplicity leaves it devoid of the attractions

[4] *Ibid.*

that more complicated, more esoteric explanations frequently have. Then, too, simple accounts have the disadvantage of appearing to lack profundity, yet the reader surely understands that an apparent lack of profundity is hardly grounds for dismissal. In order to see, then, why Newton's laws require physics to become mathematical, let us begin by examining some of the elements of the Aristotelian theory his laws replaced.

B. The Greek View: A Rough Description

To the man who, like Aristotle, looks at nature with no more equipment than his unaided senses and intelligence, the local movements of natural bodies are difficult to explain. If we put ourselves in the position of having to start our science from scratch, without instruments, we find that we can do little more than make some common observations. When natural bodies are left to themselves most of them fall to the earth, while a few rise. Fire, for instance, tends to rise up from what is burning, air bubbles upward from the bottom of a lake, stones fall to its bottom, and ordinary objects fall to the surface of the earth when they are released in the atmosphere. In short, when things are left to themselves they tend to move either up or down in relation to one another; that is what we observe in a natural, non-laboratory, non-imaginary environment. Now in order to explain such movements Aristotle postulated, as had some of his contemporaries, that there were four elementary substances: fire, air, water, and earth (what we would call rock, stone, or mineral). Grounding himself on observation Aristotle held that these four elements differed by reason of being light and heavy bodies; fire and air were light, water and earth were heavy. The qualities of light and heavy were the two characteristics which accounted for the different movements to which natural things are subject. Fire, moreover, was regarded as light in an absolute sense; air was considered light in relation to water and earth but heavy in relation to fire, while water was considered heavy in relation to air and fire but light in relation to earth; earth was heavy in an absolute sense. Furthermore, these natural movements were thought to have built-in directions; the downward motions were toward the center of the universe (which was at the center of the earth), the upward motions were toward the outer part, the boundary of the universe. Mixed substances (compounds) tended to rise or fall according to the element or elements which predominated in them. Thus, every elemental substance (as well as the compounds made from them) was thought to have a natural motion corresponding to its constitution as light or heavy: fire and air, which were classified as light elements, tended to rise and occupy higher regions; water and earth tended to fall and occupy lower regions.

Of course the source of the natural up and down movements is not observable. Nothing can be seen to push or pull natural bodies; they appear to move by themselves, spontaneously, as the modern physicist says. Hence to account for these natural motions Aristotle theorized that they were necessary properties of the heavy and light bodies. According to his hypothesis, as soon as a heavy body came into existence it began, unless impeded by something, to fall toward the center of the universe, the earth; and as soon as a light body came into existence it began, unless impeded by something, to move toward the outer boundary of the universe. In other words, Aristotle defined the two sorts of bodies according to their up and down motions, a heavy body being one that moved toward the center of the universe, a light body being one that moved toward its boundary. (The definitions were founded on natural qualitative differences in the movements.) In this way he explained why the lower or interior parts of the planet were composed of earth (mineral) while the seas (water) were located above the earthy materials and the air above the seas and the earth. In short, the differences of light and heavy accounted for the relative movements and locations of natural stuffs in relation to each other in the same way that modern physics accounts for the relative positions of substances in a gravitational field on the basis of their relative densities. The more dense bodies are closer to the center of mass; the less dense are farther from the center of mass. One is not surprised, moreover, to find some similarities in the explanations, for the observations to be accounted for are the same, whether the times be ancient or modern.

It is also interesting to note that modern physics considers the photon to acquire its motion in the same way as Aristotle's heavy and light bodies, although the photon is not assigned a determinate direction toward a theoretical center or boundary of the universe. We are informed that photons move at a speed of 300,000 kilometers per second simply because they exist as photons. If one asks, what would happen to a photon were its motion arrested, he is told that it would cease to exist as a photon. In other words, motion belongs to the photon as an inseparable, necessary property. Unlike Aristotle's heavy and light bodies, however, the motion of a photon cannot be impeded without destroying the latter as an entity.

Returning to Aristotle's theory, one ought to note that natural bodies do not always move in relation to each other according to their constitutional inclinations; for when men or tornadoes or the like cast stones into the air the motion that is imparted to them clearly results from an extrinsic agency, and the imposed motion is opposed to the spontaneous tendency of the stones to fall. Such movements Aristotle said were violent or compulsory. He regarded natural and compulsory motions as qualitatively distinct owing to their different sources and orientations. Natural motions were either up or down, while violent motions opposed either the upward movements of light bodies or the downward movement of heavy bodies.

In addition to the events that happened on the surface of the earth, Aristotle attempted to account for the behavior of the stars and planets, and needless to say, they too presented explanatory difficulties. To all appearances the stars and planets described—over a period of time and with some secondary motions—circular orbits about the earth. On that account Aristotle theorized that they were located on various spheres, the uppermost of which was the boundary of the universe. And it is important to note that up to Aristotle's time, as far as observation showed, the stars and planets appeared to differ from terrestrial bodies by (1) the absolute regularity of their movements, and (2) by their permanence. The astronomical records available to Aristotle showed no occasion on which a celestial body had either deviated from a regular orbit or come into or passed out of existence. Such data suggested to him that stars and planets, unlike terrestrial bodies, were neither produced nor destroyed by any natural process, and so he assumed this to be true. Furthermore, in order to explain their apparent incorruptibility, he had to assume also that celestial bodies were composed of a matter wholly unlike that of terrestrial substances.

The celestial bodies were assumed to differ in the sources of their movements, too. The stars and planets were thought to move circularly by reason of being continuously affected by extrinsic intelligent agents that were not themselves a part of the material universe. According to Aristotle's theory, the circular motions were natural in the sense that the celestial bodies had an aptitude for being affected by the extrinsic causes, not in the sense that they followed necessarily on the constitution of the celestial bodies. In short, celestial bodies were thought to be quite unlike terrestrial elements and compounds.

In summary, then, the Aristotelian theory was formulated to explain what ordinary experience revealed. It postulated several *qualitatively distinct kinds of motion and qualitatively distinct causes for each.* And so although the foregoing description is brief, it contains the essentials of what the scientific revolution overthrew.

C. The Modern View of Motion

During the medieval period the Ptolemaic mathematical (geometrical) astronomy was employed to supplement Aristotle's physical explanations. Ptolemy's fundamental assumptions were not in any important way opposed to Aristotle's, although the mathematical theory did find it necessary to assume that the earth was not quite at the orbital center of the universe. The geometrical theory was very successful in accounting for the observable behavior of astronomical bodies, and its success helped to solidify the Aristotelian physical theories. Consequently the introduction of a heliocentric hypothesis of planetary motion, after Copernicus, did more than destroy Ptolemy's mathematical account; it also destroyed, as Koyré observed in the passage cited earlier, the cosmos, that is, the Aristotelian theory of celestial bodies and the causes of their movements. The first step in this new direction was not made, however, without new data; for despite its complexity the old theory was intellectually sophisticated, and it had accounted for the observations rather well; hence it did not topple readily. But new data was not easy to come by: one cannot simply look out into space and observe the planets orbiting the sun. Some of the data was of course supplied by the observations Galileo made with the newly invented telescope. He observed the moons of Jupiter and was able to determine that they revolved about the parent planet; and although the movements of moons do not, as many have noted, directly confirm a theory of planetary revolutions about the sun, they do support such a theory by way of analogy. The bulk of the new data was supplied, however, by Tycho Brahe, who had worked many years with refined instruments of his own design to acquire it. He amassed a very large amount of new information, having made countless observations on the positions of planets and stars at various times of the year. Kepler, who was Brahe's student, continued his teacher's work, but only with the head start he had received could he have formulated the laws of planetary motion which were so important to the scientific revolution.

Yet it must be emphasized that the new astronomy did more than describe planetary orbits; the heliocentric hypothesis carried with it many additional implications. First in importance is the implication that celestial bodies are not composed of a matter radically different from the matter found on the earth. If the face of the moon is seen (with the aid of the telescope) to contain many irregularities, if the earth is not the center of the universe, if the planets revolve about one star among millions, then it seems more reasonable to assume that terrestrial and celestial bodies are composed of the same kind of matter. In addition celestial bodies can no longer be singled out as incapable of production or destruction by natural agencies, however infrequently such events may happen. If celestial bodies are made of the same kind of materials as terrestrial bodies, then there is no reason to think of them as being moved by causes different from those that move bodies on the earth. Also, if the earth revolves about the sun, then the elements can hardly be thought to move toward the center of the universe or toward its boundary by reason of being heavy or light. In short, once the dike had been pierced—to use an old metaphor—the trickling water soon became a flood, sweeping before it the entire edifice of Aristotelian natural science. The fall of that edifice prepared the way for Newton.

D. A New Causal Theory.

There seems to be little doubt that the most serious weakness in the Aristotelian theory of local motion was the account it gave of projectiles, which are instances of what Aristotle called violent motion; and violent motion is, the reader will recall, imposed upon a body by an extrinsic agent in opposition to the body's natural tendency to fall or rise. Aristotle theorized that after the projectile had separated from the agent (a human hand, catapult, sling, etc.), its continued motion was caused by a complicated movement of the air through which it traveled. (In ways that we cannot discuss here his theory seemed to require continuously acting agents to sustain violent motions.) From rather early times this part of Aristotle's theory met opposition, but not until the medieval period did its chief opponent, the impetus theory, become accepted. The important advantage of the impetus theory was that it did not require a continuously acting agent to sustain violent motions; instead it held that contact between an agent and a moved body was necessary only at the beginning of the motion. Thomas Aquinas stated the relevant principle as follows: "It is necessary that mover and moved exist simultaneously with respect to the beginning of the motion but not with respect to the entire motion, as is evident in projectiles." [5] Such a principle requires motion to be regarded not as transient but as enduring, which means, to repeat the point, that motion does not need the continued action of an agent to keep it in existence. On those grounds one seems justified in saying that the notion of impetus contributed importantly to preparing the way for Newton's theory of mechanics.

Newton formulated his first law of motion as follows: "Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it." The physical principle is very clear in what it says: neither motion nor rest follows necessarily on the

[5] Thomas Aquinas, *Questiones Disputatae de Potentia* (Rome, Marietti, 1949), III, 11 ad 5. Perhaps this is as good a time as any to note that many steps had been taken toward the modern scientific view before Newton; he did not propose a theory for which there was no preparation. Newton made use of Galileo's contributions to an understanding of inertia, for example, and he also got from others the notion that forces could be composed. But this essay is not historical in its aim, so we shall focus on Newton's contributions, since he firmly established the modern theory of motion, which *requires* quantification.

constitution of a body. A body in a state of rest will remain in a state of rest unless an extrinsic force affects it; a body that is moving will continue to move in a straight line at a constant speed unless an extrinsic force acts upon it. Physicists are quick to point out, however, that an absence of extrinsic forces can be understood in two ways: either no forces whatsoever are acting on a body, or the forces acting on it are balanced, which means that their vector sum is zero. Stated negatively the first law means no unbalanced force is affecting the body. Thus, the only state of affairs requiring an acting cause, a force, is an acceleration, which by definition is a change of speed or direction. To repeat: *according to Newton, the only detectable effect for which a cause can be assigned is an acceleration.*

According to the new theory an acceleration is not determined by reference to known, qualitatively distinguished parts of the universe. Rather an acceleration is established by reference to a set of coordinates, and whether it be a change of speed or a change of direction, acceleration is a variation in a motion that is a *more or less.* That differences in speed are differences of more or less is obvious, for speed is an indication of how fast or slowly a body is traveling. But in the new physics a change of direction is also to be regarded as a difference of more or less; for when directions are no longer defined absolutely in relation to parts of the universe but are described as angles measured from coordinates, direction too becomes a difference of more or less. To use contemporary terms, directions are distinguished quantitatively rather than qualitatively. Even movements that are oppositely directed and represented as positive or negative come to be regarded as having no absolute qualitative differentiation of direction in relation to the universe.[6] In short, Newton's first law tells us that the only difference in the motion of a body that can be causally explained is a difference of more or

[6] Even when in theory boundaries exist, as long as they are unknown they cannot define directions.

less; thus considerations of moving bodies are no longer founded on qualitative distinctions of the kind that characterized Aristotelian physics.

Now it is plain that in order for differences of degree to be known precisely they must be measured. Consequently the new physics was obliged to become quantitative, for according to its fundamental philosophical position only variations in speed or direction had causes that could be detected. And once the official data of physics became numbers standing for measurements, then all correlations of data had to be represented by mathematical propositions, for every relation between numbers is a mathematical relation. This amounts to saying that Newton's view on the cause of motion made mathematics as necessary for physics as measurements. For that reason one is inclined to think that the mathematization of physics was not the result of a new metaphysical point of view; it was, on the contrary, the direct result of a new theory on the causes of local notion. The Newtonian view does not of itself make motion intrinsically mathematical; it remains a physical phenomenon. For that reason it seems to me that the birth of modern physics ought not to be looked upon as the consequence of a metaphysical theory that turns the nature of physical realities into mathematical entities in the manner of Pythagoras. But the point bears elaboration.

Not every difference of degree, intensity, more or less, is a difference that is mathematical in nature. To be sure, as soon as the official data or starting points of a natural science become measurements, then every *observable* that is *immediately relevant to the explanatory process of the science* is correlated insofar as it is measurable with a number representing a measurement. Because ordinary observations of differences of degree such as fast and slow, high and low, right and left, hot and cold, heavy and light, hard and soft, etc., are too imprecise for scientific considerations, qualities or characteristics of bodies other than magnitude (extension, dimension) which provide data for the sciences are correlated with that sensible trait in which differences of degree are most clearly and determinately recognized, namely, length. A thermometer, for example, is a device that measures how hot or cold something is, but the thermometer does not tell us directly about that which we sense when we say something is hot. Instead a thermometer allows us to correlate the quality *hot* with a column of mercury, which in turn is correlated with graduations on a scale (itself a length) placed alongside the column of mercury. Neither of these is what we sense when we feel something is hot. Nevertheless numbers are the official data of physics when it deals with heat phenomena because, as was said, numbers are directly related to something more easily observed than differences in the intensity of heat. Briefly, what the scientist directly observes when he measures temperature is not the hot but the juxtaposition of two lengths. It must be added that sometimes measuring devices are employed in which the observed length is an arc, which is often scaled in degrees instead of meters or fractions thereof; yet in that case too what is observed is a length on a dial marked with graduations with which a meter needle coincides more or less closely.[7]

Now although motion is measured by length, motion is not length. To measure velocity one must measure the distance (a length) over which a body travels and compare it to the arc (a length) measured off by the hands of a clock. Plainly that which is directly measured is not that which the physical consideration seeks to explain; rather, the lengths are used as means

[7] Of course physicists measure time by using some simple, periodic motion to determine the duration of events, and they sometimes represent the results on digital counters. But in these cases, too, what is less easily observed is correlated with something more easily observed. Digital counters are merely a more sophisticated extension of pointer readings. Our discussion is directed, however, more at the physical properties of bodies than at time.

by which the mind can come to an understanding of motion. And so the conclusion to be drawn, it would seem, is that physics became a mathematical science because (1) it seeks causal accounts of differences of more or less in motion, and because (2) differences of more or less in movements can be accurately known only by correlating them with differences in something which can be directly measured and more accurately observed than the differences they help us to know.

The account that has just been given of mechanics fits some other parts of physics. Electrical forces produce accelerations and in that respect are treated in the way that mechanical forces are: no acceleration, no detectable causal agency. Thermodynamics considers heat phenomena, which, as its second law reveals, are dependent on differences of more or less in relation to temperature, and only in the presence of such differences can work be done. Nevertheless the position taken in these pages should not be read as saying that every application of mathematics to natural entities is identical to mechanics, for that does not appear to be true. Chemistry furnishes a case in point.

If my imperfect understanding of its history is correct, chemistry was not solidly established as a quantitative science until experimental observation showed that reactants combined in definite proportions according to ratios that are represented by whole numbers. Although measurements were made, they were correlated not according to regular variations but according to determinate proportions. Once this fundamental discovery was made, the groundwork had been laid for considering natural substances as being composed of indivisible particles; and in dealing with atoms, one applies numbers not to magnitudes but to collections, which is another way in which realities can differ according to a more or less. Still other ways can be found in which quantitative considerations are made, but their existence does not prejudice the position taken here. Mechanics is a fundamental science, and its character as quantitative can be appropriately used in determining how philosophy is to be distinguished from the natural sciences, for as was said in the beginning, the quantitative aspect of the natural sciences separates them from natural philosophy, originally the science of nature.

Having finished the discussion of the initial question—why the natural sciences began to measure when they did—one has in his possession the basic characteristic of mechanics that explains the nature of mechanics qua science, as well as the nature of all the other sciences that measure by reason of similar postulates about the cause-effect relations among the physical changes appropriate to their subject matters. Moreover, what has been said up to now will explain not only the nature of a quantitative science but some of its primary properties as well. The properties at issue are those which Duhem assigns to laws.[8]

It is plain that once the official data of a science become number-measures the official propositions of the science become algebraic (rather than verbal) expressions, however much words may be necessary in order to attach the symbols to physical realities. Laws, then, are appropriately described as algebraic symbolizations of regularities in nature. And since numbers are assigned to physical properties by means of measurements made with a physical instrument that can never—for a variety of reasons well known to all who study these issues—correspond *exactly* to what is measured, the laws themselves never correspond *exactly* to the regularities. Exact correspondence, however, is what truth implies; consequently laws, as Duhem observes, are not in the strict sense true or false, but approximate. Being approximate they are also provisional, for approximations can be made better and better over a period of time. But the point is not to repeat what is commonly known; rather it is

[8] Pierre Duhem, *The Aim and Structure of Physical Theory*, tr. Philip P. Wiener (New York, 1962), ch. v.

to note that when a science postulates that the only differences for which it can give a causal account are differences of more or less, its laws, its explainable propositions, become approximate rather than true or false. In short, this property of the laws follows from the basic causal assumption of the measuring science.

But Duhem assigns a second reason why laws are provisional. They are provisional, he says, not only because they are approximate but also because they are symbolic. One must hasten to note, however, that the peculiar nature of the symbol qua physical is what is at issue here, otherwise every symbolic representation in every science would have a provisional character. Now if one focuses on the character of the physical symbol when it is applied to a measurable physical characteristic that needs to be explained, he lays the groundwork for an examination of the main questions for the sake of which these first considerations have been undertaken, namely, whether there is a natural philosophy and if so what it is. Hence because the symbolic character of physical laws leads directly to these primary issues, it will introduce the discussion in the following section.

E. What, then, is Natural Philosophy?

It would seem that the fundamental character of the new physics as a systematic discipline becomes evident as soon as one understands that mechanics account for accelerations. To recapitulate a point or two, since physics must measure, it accepts only numbers as its official data, pointer readings, as Eddington says. Numbers that are obtained by observation, represent measurements, and these are the fundamental numbers because they link the mind to reality. Of course other numbers. too, play a role in the physical sciences, and these are (1) numbers calculated from measurements, and (2) numbers postulated to explain measurements.

Measurements, however, which are the fundamental numbers, represent differences that presuppose a qualitative homogeneity on the part of the realities that differ according to a more or less; and this is a point central to the present issue. For instance, motions that are faster or slower are both changes of location; temperatures, whether higher or lower, are both the same kind of sensible quality; two men, one of whom is more rational than the other (to pick an example at a great distance from the realm of physics) have the same kind of cognitive capacity. Differences of degree plainly do not make differences of kind. The point, however, needs further consideration.

That quantitative differences presuppose qualitative homogeneity is obviously true when one relates two or more instances of characteristics such as distance, temperature, voltage, resistance, light intensity, volume, etc. That quantitative differences presuppose qualitative homogeneity is also true, though not so obviously nor in the same way, when one relates temperature to volume, pressure to temperature and volume, etc. Temperature, pressure, and volume are all qualitatively—that is formally—different attributes, two of which are causally related to the other; for differences in temperature and pressure effect differences in volume. Temperature and pressure are also causally related to each other when volume remains constant. One cannot escape, however, relating each of these qualitatively different attributes to a length in order to measure them, and when that is done they "artificially" (for want of a word) become homogeneous; that is, they become homogeneous by their common relations to the medium of measurement, length. Pointer readings mark off lengths, whether in degrees or meters, on graduated scales. As a result of qualitatively different characteristics becoming "artificially" homogeneous in this fashion, physical symbols abstract from the qualitative differences and all the qualitative cause-effect relationships the characteristics found. Of themselves, therefore, physical symbols signify differences of more or less, but only on the condition that they are first attached to physical realities by means of verbal expressions. Consequently physical symbols are nearly—but not quite—as abstract as purely mathematical symbols. Now this kind of symbolic representation of physical qualities allows the scientist to increase continually the number of conditions that he takes into account in calculating physical values. For this reason, too, Duhem points out, physical laws must be regarded as approximate.

As a further consequence of such abstraction, more specific notions, for example, the distinction between primary and secondary causes and primary and secondary effects, go unconsidered. (To avoid a misunderstanding the reader ought to note that here "cause" is used to mean something quite general: that upon which the existence of something else—an object or an attribute—depends. Obviously the notion applies to more than an agent or mover of some kind.) Thus, homogeneity and precision in measurement and observation come at a price: in abstracting from qualitative differences, the official propositions of the mathematical sciences of nature abstract from all cause and effect content as well as from many other important distinctions. *Unofficially* such content exists, of course, but it is not systematically presented in terms of *general qualitative categories and definitions, arguments,* etc., that derive from (incorrigible) common observations.[9] There is, then, a lacuna in the mind's understanding, which leads us directly to the issue of what natural philosophy does and therefore to what it is.

Describing natural philosophy very generally, its function

[9] That some observations remain uniform throughout history is obvious to everyone, and the point has been made often. The physicist, for example, supposes that the laws of mechanics, which he uses to describe the past, held in the past according to their present understanding. This can be true only if the same observations by which the laws are verified could also be made in the past. Plainly, then, were we to be projected back into the past, we would make the same common observations and distinctions we make now.

is to investigate systematically the common, qualitatively different characteristics of the physical background which the natural sciences presuppose. Natural philosophy will distinguish, define, argue about and in general investigate the *common* properties macroscopic entities exhibit; and in the measure possible it will attempt to give a causal account of such properties, remembering all the while that it must start with observables and justify what it says through them. On the other hand, natural philosophy does not have as its business the qualitative consideration of the *specific* physical properties and entities postulated to account for measurements; that belongs to the scientist. A few examples may be useful, for clarity on this point is important.

Physicists assign numbers to motion (velocity), to time, to distance, and to other realities. They measure some of these and calculate values for others, but they do not ask what any of them is. Physicists do not ask, what is motion? what is time? what is place (location)? Yet these questions can be examined systematically in a way that does not trespass on the domain appropriate to physics. One can define time in general without having to decide whether its measurement is relative or absolute; and he can do the same in regard to location or place as well as other properties. It is perhaps even more obvious that considerations on what motion is and what change in general is, in no way affect mechanics or any other part of physics. Furthermore, if the scientist makes a general distinction between categories of change on the ground that some are chemical and some are physical, in the process of distinguishing he will in one way or another have to note that chemical changes are thought to bring about modifications in substances; they are thought to bring about the production and destruction of different stuffs. Now just what is involved when a modification affects a stuff rather than one of its surface properties also requires systematic examination, and here too it may be said that the consideration in no way affects the hypotheses that the chemist may have formed about the mechanisms or processes by which the changes in stuff are thought to be accomplished.

At the other end of the category of natural sciences is the biologist, who considers living entities; but he does not systematically examine whether they are aggregates of particles, what an aggregate is, what internal states as distinct from external operations are, etc. These issues do get discussed, of course, but not by the biologist as such. (Philosophers discuss them under the heading, "Mind-Body Problem.") But then a man can wear more than one hat, which only serves to emphasize the point: however much two distinct skills may exist in one man, they are nonetheless distinct skills.

F. A Back Door Argument

As the reader knows, parts of some natural sciences are in large measure non-mathematical, one of the most obvious of them being ethology, the science of instinctive animal behavior. For the most part ethology is concerned with explaining qualitative characteristic of animal behavior; its data does not consist, in the main, of numbers nor are its theories mathematical. Can one imagine trying to explain animal movements by restricting himself to differences of more or less? But why, then, given what has been argued above, is ethology not a part of philosophy? An ethologist must, to be sure, make more observations than a philosopher, but can one regard that as an essential characteristic?

Let it be conceded at once that, in view of the position taken here, no strong case can be made for putting ethology on one side of the fence rather than the other. If ethology starts from observations, if it systematically argues, defines, classifies, etc., by taking into account similarities and differences that are not reducible to measurements, then little substantive ground can be found for distinguishing it from natural philosophy. On the contrary, a strong argument can be made for saying that ethology is an instance in which the two names can be applied to the same discipline. But such an identification is unlikely to meet with favor from ethologists, owing to impressions they may have as to what " philosophy " does in practice, and owing also to the insistence on keeping philosophy and biology distinct in accordance with academic custom. Assuming that such a long standing custom cannot be wholly in error, the objection is understandable. Moreover, it must in some measure be accomodated according to the points that have been already made, for the considerations of the ethologist are more particular, while the considerations of the philosopher are more general.

In the area of sociology and anthropology Lewis Mumford regards himself as a generalist, and the name suggests how he views his function. It indicates the kind of considerations Mumford makes on the detailed investigations of his colleagues. He compares the particulars, the details, to discover the general regularities that might belong to many distinct societies. Similarly, one might describe the function of the natural philosopher in that way.

It must be emphasized, however, that generalizing supposes data and information that are sufficient to supply an adequate inductive base for the generalizations. In short, like the generalist in sociology, the natural philosopher needs to be reasonably acquainted with the data and the more important observational regularities the physicist comes to know, although the natural philosopher need not be a physicist nor have a physicist's understanding of physical issues. In our time acquiring knowledge of natural regularities is for most people a vicarious business. We live in artificial environments that preclude our observing the behavior patterns and traits of many things in nature, and from this point of view the American Indian was considerably our superior. Most of us do not obtain so much as one regularity on the basis of our own observations. It is easily seen, then, that the natural sciences provide the philosopher with a vicarious observational contact with reality, a not insignificant service.

A second back door argument can be introduced to support the position taken here on the relation of natural philosophy to the natural sciences; for other parts of philosophy appear to stand in relation to the social sciences in the same way that natural philosophy is held to stand in relation to the natural sciences. As for being quantitative, one cannot expect the social sciences to measure with the kind of success—to understate the the point—that accompanies physics and chemistry. In the latter, useful measurements of variations in properties that are not themselves an extension depends both upon the regularity of the variations in the properties and the regularity of their correlations with magnitudes. The same variation in temperature produces the same variation in the length of the mercury column—this is a fundamental assumption, one for which no evidence to the contrary has been found. Nothing indicates that a fixed variation in temperature is correlated at one time with one variation of length and at another time with a quite different variation in length.

In sciences that deal with human behavior the state of affairs is remarkably different. Similar apples do not evoke uniform hunger responses, even in the same individual; and at times a similar apple will elicit a contrary effect, aversion, which shows that the stimulus has a correlation with hunger that is very different from the correlations between measuring instruments and physical properties. (No conceivable variation of conditions will cause a rise in temperature to bring about a shortening of the column of mercury in the thermometer.) And what is true of an elementary affective state such as hunger is true of many other human emotions, attitudes, etc. Hence the absence of dependable regularities between measuring devices and human traits means, it is important to note, that quantitative procedures cannot be applied to the behavioral sciences with the reliability characteristic of the physical sciences. Quantitative " laws " in the social sciences can hardly be put on an equal footing with the laws of physics. Of course this does not imply that every use of numbers and mathematics in the social sciences is empty. It does mean, however, that a proper understanding of the variability of human traits is required for even a limited use of quantitative procedures in the behavioral sciences. Thus, the use of mathematical arguments is subject to severe limitations in the social sciences, and if the latter are to go about their business reliably, their considerations will have to be for the most part qualitative in character. But that implies that the social sciences, too, are to be distinguished from philosophy mainly by the generality of the latter. And as in the social sciences, so in the natural.

G. Philosophy of Science

The reader is certainly aware that some of the issues that have been claimed for natural philosophy do get treated under the title of philosophy of science. When one " explicates the concepts of the natural sciences " he can hardly avoid touching some of the topics that belong to natural philosophy. Nonetheless the two disciplines ought not to be regarded as equivalent; for questions of scientific methodology, which form a large part of the philosophy of science, do not fit into the same category as substantive questions that bear directly on natural entities and their properties. Nor do the epistemological topics that are usually associated with the methodological questions belong to natural philosophy. In short, the philosophy of science has its own character and its own role to play, and one ought not to confuse it with natural philosophy.

In closing, then, I would like to note that although the foregoing discussion is but an outline, it does indicate what, in the minds of many, natural philosophy ought to do. A complete understanding of nature requires, to the extent possible, a systematic examination of the general character and attributes of natural entities insofar as they are qualitatively distinct and insofar as their differences are not reducible to differences of degree. The task, I have argued, belongs to philosophy, even though one cannot claim that the mainstream of contemporary philosophy succeeds in or even attempts to accomplish it. But the actual state of affairs matters little for the theoretical issue, and the work is there to be done.

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