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Philosophies of physics

Ann Dudley
Colby College

PHILOSOPHIES

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by

Ann Dudley

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Approved by:

Dennison Bancroft
Tutor

Richard R. Mayer
Major Advisor

Denton W. Crocker
(Senior Scholar Committee Chairman)

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INTRODUCTION

A philosophy of physics is an individual attempt to comprehend nature. For the individual who formulates a philosophy, his philosophy tells him the scope and limitations of physics, the future of physics and the worth of physics. A philosophy of physics enables its creator to grasp the happenings in nature. It gives meaning to what would otherwise be a mass of uncorrelated data and it suggests future courses of investigation; but for someone other than its creator, it may be entirely meaningless. There is no single philosophy of physics that is valuable to all men at all times.

The individual starts his search for a philosophy of physics when his scientific curiosity prompts him to look behind the sheaves of data which his laboratory work produces. He looks for a pattern into which these data might fit, and then he tests the validity of his pattern by further experiment. As he experiments, the individual questions. He asks, "What am I doing?" "What am I looking for?" "Will my method enable me to formulate laws that describe the happenings in the universe?" "Is there a 'reality' in nature for me to discover?"

At this point in the development of a philosophy of physics, one is tempted to recall the answers of "authorities".

Perhaps one remembers the positivistic view that the only reality is relationships between phenomena, and continues to take readings without a thought of their place in a world view. Possibly one remembers that Jean's sees the universe as basically mathematical. Recalling this view, one might be struck by how well his data "fit into" a certain mathematical formula, and he might accept Jean's whole philosophy without another thought. One might recall that Whitehead believes that nature is essentially a process and that the real changes. Upon remembering this view, one might be easily led to accept all of Whitehead's philosophy because experimental results seem to change with every new reading. As we can see, in the earlier stages of developing an individual philosophy, it is extremely easy to accept the philosophy of an "authority" on very little evidence.

The individual investigator will probably find that no philosophy seems to answer all his questions. The magnitude of his questions may make them difficult to answer. The impatient investigator, finding no answer in philosophy, may join some of his colleagues in shunning all philosophies of physics as metaphysical speculation. However, the patient investigator who does not find answers in existing modes of thought and who is convinced of his need of a philosophy of physics will attempt to formulate his own philosophy. This involves deciding where to start, deciding what given views are valid and looking for contradictions existing in his thought.

The "where to start" question must, I feel, be given an answer by clearing the field. There are first two areas where one should not start. One cannot successfully try to establish a philosophy of science with a decision as to the purpose of science as a basis. Bertrand Russel discusses the two major purposes of science in his book <u>The Scientific Outlook</u>. Science is either a method we use to know more about nature or it is a tool we use to control nature for the betterment or annihilation of mankind. I will not here delve into the reasons why one or the other of these views is the better purpose of science from a moral, aesthetic, or ethical point of view. This type of question, I feel, cannot be logically or lastingly settled; nor can a discussion of it lead to clearer thinking in the philosophy of natural science. It is the type of thing which is felt, instead of reasoned. The "knowledge for knowledge sake" purpose is somehow emotionally tied to the idea of aristocracy; while the "knowledge to change the world" purpose is tied with socialism. I do not wish to decide which purpose is <u>the</u> purpose of science, for I do not wish to deal with a battle of the classes. Either purpose can act as a prime mover; and with either purpose as a base one moves or tries to move in the same direction--toward more knowledge of the physical world.

Another dangerous place to start--that is another starting point that does not lead to clearer or more definite thinking in a philosophy of science--is trying to decide what we can hope to find out about the universe before we make our investigation. "It might be that we have no right to suppose that we have any empirical knowledge at all until we have performed the philosophical task of analyzing such knowledge."[1] However as Braithwaite points out, the philosopher should not doubt the proposition accepted by common sense, but he should provide analysis and clarification of them. It, of course, is natural to conclude a philosophy of science by pointing out how one's thinking tells what is useless to pursue as well as what course will be most fruitful. Pointing out the limitation of our ability to know is, however, a very poor starting point from which to develop a philosophy of science. Limitations are things a philosophy will point out to its followers after it is fully developed. The idea of stating what can be known before a complete investigation would seem to be a retarding force in finding out about nature. If an avenue of approach is really useless, investigation will show its uselessness and the investigator will not be left with a feeling of an unchecked view closed from his search by a dogmatic statement that man cannot hope to know the would-be end result of his investigation. The idea of limiting what can be known can lead to clarity of a low level fact, while making a high level hypothesis inaccessible. Stating that we can know ultimate reality can lead to false leaps over facts to nebulous statements which look to a priori reason for truth. Although one cannot fruitfully start a philosophy

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[1] R. B. Braithwaite, Scientific Explanation (Cambridge: University Press, 1953), p. 5.

of science by stating what he can hope to know, it is a human tendency to want to have some guide when going into an unknown field. Nearly everyone who is developing a philosophy of natural science will, consequently, have a preconceived notion of what he is going to find out about nature. This notion will affect his actions and thinking more than his idea of the purpose of science. Different ideas on this subject make people believe that knowledge lies in different directions. An Eddington who believes that we cannot know a "map of reality" and that knowledge of the universe is prior to experiment is not likely to spend hours collecting data. An operationalist who believes that we can only know relationships will, on the other hand, spend hours in the laboratory. Since our notions of what we can know affect our thinking and action, since it is not material for a starting of a philosophy of science, and since we naturally have preconceived notions, we must treat these notions cautiously making sure that they do not override evidence which negates them.

What then is the starting point for a philosophy of science? Since an individual is developing the philosophy, he must decide what in the universe he considers basic. What is the primary entity of nature? His answer to this question will tell him where to start to find out about nature and when he has gathered his results and formulated his laws, he can look back and discover the pattern formed by the laws. His interpretation of this general pattern will be his philosophy of natural science. His philosophy of physics will tell him what kind of a universe is made by the basic entities, it will give meaning to concepts such as space, time, simultaneity and causality, it will also show him ways in which his knowledge of the universe can be expanded as well as ways in which he is limited. Northrop has named theories of nature by the entity that the theory considers basic.

Northrop says that a philosopher of natural science adopts a physical theory of nature if he considers matter and motion as basic, he adopts a mathematical theory if he considers form as basic, and he adopts a functional theory if he considers the event as basic. The philosophy of science which is derived from a process which begins with deciding what is basic will undoubtedly develop more quickly, more clearly and more satisfyingly than other philosophies. This is because this process naturally starts with the most elementary facts and works toward the more complicated ideas, because it lends itself to logical development, because it uses a minimum of preconceived notions and emotionally tinged dogmas and because by using this process, which involves step by step thinking and action, one can tell when he "is getting nowhere". I shall use Northrop's division of theories of nature into physical, mathematical and functional because, though somewhat arbitrary, it points out the three entirely different entities which can be considered basic and because it shows clearly how terms such as wave, particle, time and causality can have different meanings in different contexts.

It must be remembered that the following discussion of theories of nature is not a complete discussion of philosophies of nature. I have called these theories of nature, processes instead of philosophies because they present step by step ways of finding out about nature. To start the process, one must choose somewhat blindly and intuitively his fundamental entity, he must then see what laws can be derived from considering this particluar entity to be basic. If following this process fails to answer his questions about the universe and to explain known facts, he can go through the same type of process while considering something else as basic. In this paper the three process which eventually emerge as the physical, the mathematical and the functional theory are traced by historically defining the three theories.

The next task on the way to forming a philosophy of science is to decide which of these theories--if any--gives a convincing view of the universe. Does one of these theories explain known facts, give a logically satisfying synthesis of knowledge and leave room for further development? It is not until an individual finds a theory that can answer affirmatively to these questions that he can really start forming a philosophy of science; for it is not until this time that he has evidence to support his choice of a basic entity in nature. Moreover, when he has found the correct theory of nature in his opinion, he can use it as the foundation and superstructure of his philosophy of physics.

We will here treat a theory of nature as a specific logical process brought into being by induction whose deductive results can be confirmed as logical or illogical, fruitful or unfruitful by a group of logical rational persons who accept its basic premise. We will treat a philosophy of science as an individual idea which is developed by looking over the particular theory or group of theories of nature which the individual accepts, seeing its limitations, its consequences and its full meaning. The individual philosophies of physics that we will examine may not begin with a decision as to the correct theory of nature and they may use the theories of nature only in a minor way. These philosophies may even be developed from the dangerous starting point of defining science or from the equally dangerous starting point of examining the "how" and "why" of human knowledge of physical phenomena. However each philosophy makes some use of the theories of nature; therefore these theories must be understood before one can discuss the philosophies connected with them. Since the theories of nature are something upon which some agreement can be reached and which fit into a logical presentation, they will be discussed in detail. Certain individual philosophies will be presented in order to reveal their connection with theories of nature. The diversity of the philosophies of physics which will be presented will indicate that an honest synthesis of philosophies is impossible and that these philosophies have a truly individual character.

PART I

THEORIES OF NATURE

CHAPTER I

THE PHYSICAL THEORY of NATURE

An Historical Definition of the Physical Theory

A physical theory takes matter and motion to be the ultimate elements of reality and states all natural laws in terms of these elements. The significance of the physical theory of nature can, I feel, be best grasped with the aid of an historical definition. This manner of defining a theory of nature reveals the important fact that the induction essential to the creation of a theory of nature is not allowed to occupy men's minds for long before the deduction essential to checking a theory is the center of thought. The development of a theory of nature is made possible by the fact that induction and deduction are both at work all the time. A systematic deductive framework appears only when one views in retrospect the history of a theory. The ordered deductive system, which is a scientific theory as proposed by Braithwaite, attempts to explain lowest-level propositions, which are observable facts, by deducing them from more general hypotheses at one or more higher levels.[1] After historically examining

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[1] R. B. Braithwaite, Scientific Explanation (Cambridge: University Press, 1953), p. IX.

the physical theory one sees just such an ordered system develop. The high level hypothesis that the fundamental entities in nature are matter and motion leads to low-level generalizations concerning observables, such as the rate at which an apple falls to earth, or the wavelengths of the spectral lines of hydrogen. As this historical definition will show, observable phenomena come to man's attention before man develops the logically prior high-level hypotheses.

As early as 640 B.C. the Greek atomists developed a type of physical theory. The atomists, by considering stuff and change to be fundamental in nature, captured the essence of all physical theories. Democritus (C. 400 B.C.) wrote, ". . . only the atoms and the void are real."[2] Physical theory, however, did not dominate Greek thought. The Greek proponents of the "stuff and change" theory were working under a handicap because a physical theory gets its strength from quantitative experimental facts, and since the Greeks ignored experimental data, the theory of the atomists had to remain what Einstein calls an "ingenious figment of the imagination."

Yet the appeal of a theory that allows man to deal with simple, discrete particles instead of with a complex continuum is strong. Partly for this reason, physical theories and their offsprings appear frequently in the history of science.

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[2] Albert Einstein and L. Infield, The Evolution of Physics (New York: Simon and Schuster, 1938), p. 56.

Northrop says of a physical theory, "Since its facts are obvious extensive characteristics of observed nature, and possess a universality which findings of the technical sciences cannot enjoy, we must expect this theory to possess a certainty and a lasting quality which none of its rivals can equal."[3]

Whether the facts of a physical theory are obvious or universal, or even meaningful may well depend upon how far one has come along the trail that leads to an understanding of natural laws. What is real and obvious for the beginner is often a substanceless apparition to the expert and conversely. In discussing various theories of nature, one must avoid the maze of epistemology. How one knows--to the extent that it is important--is given in the process of tracing different theories that show how men have known. What is real and what is apparent changes not only with changing theories of nature, but also with changing species of the same theory. A discussion of theories of nature need only make plain appearance and reality within a given theory.

The important feature of a physical theory of nature in terms of the previous discussion is that on the lowest, or beginning level of investigation, it does seem to be the obvious theory. If we are meditative investigators, as were the atomists, we begin by viewing the world around us. The trees, the rocks, and other people are real and obvious

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[3] F. S. C. Northrop, Science and First Principles (New York: The Macmillan Company, 1931), p. 11.

on this level. We do not conceive a rock to be bits of energy or a field of waves. On this same level we are aware that some things are moving and some things are still. Being of a meditative nature we sit and think. If we are searching for recurring patterns of reality, we can not admit that every object in the universe is a fundamental part of nature nor can we admit that the various kinds of motion are fundamental; but we can say that matter and motion are fundamental. As can be inferred from the above, a physical theory would be obvious on this level for the meditator.

If we were empirical investigators, we would begin our attempts to understand nature with something near-at-hand as did the meditators; but we would not be satisfied with a vague and qualitative description. The rocks, the trees, and the motion of a bird would still be real for us. Although we would believe that matter and motion were somehow basic, we would want to know--if we were a Galileo or a Newton--how much matter produces how much motion. We would desire quantitative knowledge of interactions in nature.

Pushing blocks of different sizes and dropping stones out of towers would give the empirical investigator quantitative knowledge and would become, for him, important experiments. Even though the empirical investigator has progressed to quantitative study, he is still on the beginning level where the facts of a physical theory are obvious and meaningful in light of his discoveries. Matter and motion are still basic.

The first person to use a physical theory of nature supported by experiment was Galileo. Since the natural support of a physical theory would be experiment, it is not surprising that Galileo, the searcher for empirical knowledge, was instrumental in bringing about a two hundred year reign of physical theory. Science comprising experiment and theory really began to function with Galileo.

Galileo in his time seemed to be a philosophical revolutionist. Although he was returning to what Northrop calls the first principles of a physical theory, his contemporaries saw him as a man defying the old established Platonic and Aristotelian science, in order to present new ideas of nature. After centuries of the form-stressing theories of Plato and his followers, and after the middle ages when emphasis was put on Aristotle's functional theory, Galileo appeared in the early seventeenth century to proclaim that forces and mass not being or becoming were fundamental. This return to a physical theory was indeed a sharp change in thought.

Galileo affected his world greatly not because he as a physicist proposed a physical theory instead of a functional theory, but rather because his proposals contradicted Aristotle's functional theory which was tied strongly to the tenets of the Catholic Church. Physical theories are not suitable for an authoritarian system such as that of the Church, because with one experiment all previous beliefs can be invalidated. No fixed system of truth can be established under first principles that make experiment with the physical world the court in which ideas are tried. As Northrop says, "the methods of science have no respect for tradition."[4] By contradicting the previously established functional theory, Galileo was advocating a system that could be used to undermine the authority of the Church.

The vague Greek idea of matter became, in the hands of Galileo and his followers, the definite quantitative idea of mass. The Greek idea of motion metamorphosed into the Galilean idea of acceleration. Then came the idea of force. Galileo discovered the concept of force and Newton presented it precisely.[5] The concept of force followed the concept of motion because investigators went beyond noting that an object moved when pushed or dropped, and asked themselves what makes an object move in just a certain manner. Galileo conceived force to be that which produces a time rate of change of velocity. The concept of force as we know it was born with Galileo's experiments.

Galileo brought science down to earth and made it of practical use. Instead of calculating planetary masses and paths, Galileo decided to find out what determined the final velocity of an insignificant earthly object which he dropped from a height. The final velocity obviously

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[4] Ibid., p. 31.

[5] Einstein and Infeld, p. 9.

depended on the object's weight, its distance from the ground and the time of fall, but which of these determined the object's terminal velocity? The image of Galileo dropping objects of different weights from the tower of Pisa floats down through history unconnected with his purpose. Galileo merely wished to find out if the final velocity of a massive object was proportional to its weight. The weights landed at the same time. If one had been going faster than the other, it would have reached the ground sooner. Final velocity was, therefore, not proportional to mass. Galileo did not depend entirely on experiments for his momentous discoveries. He was greatly aided by his intuitive genius, as evidenced by the fact that he had no certain experimental evidences for deciding that the velocity of the dropped object did not depend on the distance. He, however, decided correctly that the final velocity was proportional to the time of fall, and was led to his famous experiment with an inclined plane. With this experiment he established the relationship between distances and time that was essential to a belief that the final velocity depends on time of fall. If a plane is inclined, it is capable of producing an acceleration, and therefore, a change in velocity with time. It is evident that the time it takes the ball to roll down the inclined plane determines its final velocity. The longer it takes the greater the change in velocity and the greater the final velocity.

Because of Galileo's work the concept of time became important.[6] Force, one of the fundamental aspects of nature, according to Galileo's physical theory, was known to produce not velocity, but a rate of change of velocity. Galileo's work with the inclined plane foreshadows Newton's first law of motion, which embodies the principle of inertia. With the aid of considerable insight it was seen that if the plane is horizontal no acceleration is present and a body that ceases to be pushed will not stop moving; it will stop changing its rate of motion. It will continue to move in a straight line if no friction is present. As Newton later stated:

> Every body continues in a state of rest or in uniform motion in a straight line unless acted on by some force.

The physical theory of nature gained more support as time moved on. Its meaning was extended by the men who supported and used it, and the logical implications of its major premises were further explored. Newton, born in 1642 (the year Galileo died), developed a systematic statement of mechanics and established the validity of the physical theory in the far-away as well as in the near-at-hand. Combining Galileo's ideas with the results of his own experiments, he was able to add a second and a third law of motion

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[6] Northrop, in discussing this idea in his Science and First Principles, questions the elemental nature of the concept of time. He says that since the concept of time did not arise until after technical science founded on a physical theory of nature was developed, time must find its basis in matter and motion. Time would then not be basic.

to his previously stated first law. The second law of motion stated that the time rate of change of momentum of a body is proportional to the resultant force acting on the body. This was later interpreted as stating that force equals mass times acceleration.

The second law of motion is implied by Galileo's work. As we have seen, force was known to produce acceleration. Newton added a clear statement of the condition by observing that force equals mass times acceleration. The third law stated that to every force acting on one body there is an equal and opposite force acting on another body. We have derived from this law the law of conservation of momentum. Momentum is the product of mass times velocity.

Newton's principal contribution to the strength of the physical theory is that his systematic development of mechanics, a science which is based on physical theory with force and mass as fundamental, proved so satisfactory in explaining the motion and predicting future positions of both terrestrial and celestial bodies that it served for over two centuries as the prevailing theory of nature.

Newton showed that the law of nature that applied in the case of an apple falling to earth was the same law that applied in the case of the moon falling toward the earth as it revolves about the earth. This he called the universal law of gravitation, it states that the force which exists between two bodies is equal to a constant times the product of the masses divided by the distance between the bodies squared. There still remained a problem for the genius of Newton to solve. In Newton's statement of the law of gravitation, the masses are considered to be particles; however, the earth in relation to a falling apple is hardly a particle. Where, then, could the mass of the earth be said to be acting. To find the appropriate distance between the apple and the earth Newton is said to have invented the calculus.[7]

With the formulation of the law of gravitation, the physical theory was at the height of its glory. One only needed to know the straight line distance between two bodies and their mass in order to know the force acting between them. Galileo's work tells us that force is the only thing that can affect the future path of a body. Knowing the forces acting on bodies and their present position, one could predict the path of the body, and thereby predict a future state of nature. The mystery of nature seemed to be solved. Could not man assume that he knew the workings of nature if he could predict the future state of objects on earth and in the heavens?

> The astonishing success of classical mechanics suggests that the mechanical view can be consistently applied to all branches of physics, that all phenomena can be explained by the action of forces representing either attraction or repulsion, depending only upon distance and acting between unchangeable particles.[8]

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[7] Reginald J. Stephenson, <u>Mechanics and Properties of Matter</u> (3rd ed.; New York: John Wiley & Sons, 1958), p. 84.

[8] Einstein and Infield, p. 67.

At this point the physical theory's link with determinism, one of its chief features, is brought forward. It follows logically from the assumption that the fundamental entities of nature are matter and motion, that if one knew the forces acting on these entities and their direction of motion, one would have vital knowledge of the workings of nature. This knowledge gives one the ability to tell what has happened and to predict--or determine--what will happen. The historical link between determinism and the physical theory may have its foundation in the fact that the physical theory allows man to think in terms of finite discontinuities. The handling of discrete manageable items may give man a sense of being able to control and to predict the action of these finite units; and thereby, the action of the universe that they compose.

It may be the success of the physical theory, in the form of classical mechanics as presented by Newton, in explaining natural phenomena to a first approximation that made so many nineteenth century physicists reluctant to give up classical mechanics even when the field theory of Maxwell brought optical and electrical phenomena together so beautifully. These same physicists clung to the ether as a frame of reference for electromagnetic disturbances long after the ether became a futile concept. "Classical science assumed that those manifestations we call electricity, magnetism and light were nothing but strains in an imponderable medium the stagnet ether, floating in space."[9] The physicists of the nineteenth century seem almost to have forgotten their empirical heritage in the presence of the success of their theories. A physical theory gets its life blood from experiment. When it takes the authoritarian form in which it appeared frequently in the nineteenth century, there is every reason to believe it will stray away from the road that leads to meaningful discoveries. Poincare in discussing the place of empirical evidence and generalizations provided a key to the error of his nineteenth century predecessors who put too little stress on empirical evidence as well as to the errors of those who stress empirical evidence beyond the point where it is valuable.

> "Experiment is the sole source of truth. It alone can teach us something new, it alone can give us certainty . . . (but) it is not sufficient merely to observe; we must use our observations and for that purpose we must generalize. This is what has always been done, only as the recollections of past errors has made man more and more circumspect, he has observed more and more and generalized less and less. Every age has scoffed at its predecessor accusing it of having generalized too boldly and too naively. . . Can not we be content with experiment alone? No, that is impossible; that would be a complete misunderstanding of the true character of science. . . Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house."[10]

Experiment and generalization are both crucial to scientific

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[9] A. d'Abro, <u>The Evolution of Scientific Thought</u> (2d ed.; New York: Dover Publications, Inc., 1949), p. 116.

[10] Henri Poincare, <u>Science and Hypothesis</u>, trans. W. J. G. (New York: Dover Publications, Inc., 1952), pp. 140-141.

progress. We shall see that some nineteenth century physicists overemphasized the generalization and ignored the experimental evidence. This attitude was to change gradually with the coming of the twentieth century until in the mid-twentieth century, we do not have enough valid generalizations.

The success of Newtonian mechanics may also be the reason that the physical theory was kept in more or less static form from Newton to Einstein. In many ways Einstein's relativity theory is the ultimate physical theory. Northrop graphically describes the ways in which the relativity is a physical theory. Einstein, however, goes beyond the physical theory as presented by classical mechanics and in doing so renders useless such concepts as its ether. Einstein can be represented as the man who put the physical theory of nature back on the right tracks.

In The Evolution of Physics, by Einstein and Infield, one can find (1) the reason that mechanical views had to fail and (2) the way in which Einstein went beyond classical mechanics. The following evidence for the decline of the mechanical view is taken directly from Einstein.

The first crack in the armor of the mechanical theory is revealed by a discussion of the experiments of Oersted in which the force between a current carrying wire in a loop and a magnetic pole in the plane of the circle is shown to be a force perpendicular to the plane of the wire loop and to depend on the velocity of the charges in the wire. This is contrary to the mechanical view in which, "We remember that the forces of gravitation, electrostatics and magnetism, obeying the laws of Newton and Coulomb, act along the line joining the two attracting or repelling bodies."[11] We shall leave Oersted for a moment in order to view the field of optics.

A second trouble for the mechanical view came in optics. The natural thing to assume under a physical theory is that light consists of hard little balls travelling in straight lines and causing a sensation on the retina. An explanation of refraction, reflection and color can be made in terms of a corpuscular theory by adding ad hoc hypotheses; but the refined experiments that showed diffraction of light around opaque obstacles seriously impaired the corpuscular theory of light. The fact that Young and others showed the "bending" of light does not disprove the corpuscular theory; it requires only that supporters of the corpuscular theory weight their theory down by adding new substances and ideas. To discover the theory that most nearly explains the workings of nature, one must discover the theory which from its basic assumptions can clearly and logically explain a phenomenon without the addition of undue ad hoc hypotheses. Einstein points out that the first persons to discard the corpuscular theory of light formed a type of wave theory. The wave theories that came directly after Newton were still <u>physical theories</u> because the waves of these theories were

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[11] Einstein and Infield, p. 92.

seen as spreading in a medium which, though imponderable, behaved like a physical solid. The theories of light did not jump immediately from ideas of light as hard spheres to ideas of light as a substanceless electromagnetic wave. It took a long time for physicists to change their first principles from the physical theory as presented by Newton to the formal theory as presented by Maxwell. Even after the change things were not settled.[12]

Returning to the problem of Oersted's pole lying in the same plane as and inside of a loop of wire, Einstein shows how the mechanical explanation really began to give way to the formal field theory. The fact that the pole moved perpendicular to the plane of the loop when a current was passing can be explained readily by assuming that the moving charges cause a field around the wire. The lines of force of the field encircle the wire at every point causing as a total effect a force perpendicular to the loop of wire. This force acts in the plane of the magnet. This diagram appears in Einstein's explanation and explains the situation.

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12 The corpuscular theory of light was not dead. Einstein himself gave further validity to the corpuscular theory by presenting the photoelectric effect. Einstein received the Nobel prize for his work with the photoelectric effect. Although it was now energy or photons that was in bundles, the bundles of the corpuscular theory reappeared. Maybe a physical theory with energy and motion as fundamental is here replacing a physical theory with matter and motion as fundamental. This however takes us too far afield.

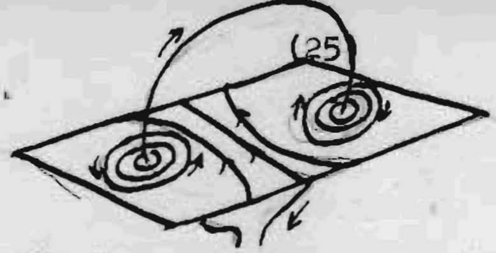

Fig. 1-1. Forces around a current carrying wire. (After Einstein and Infeld, The Evolution of Physics, p. 133.)

Electrodynamics connected with a current carrying wire caused still more problems for the physical-theory-based classical mechanics. A movable magnet with a movable closed circuit was used to reveal one of these problems. D'Abro states the results of moving first the magnet then the closed circuit, "Thus whether we displace a magnet before a closed circuit or the closed circuit before the magnet, the current induced in the wire is exactly the same in either case, so far as experiment can detect."[13] That which appears relevant is the relative motion between magnet and circuit. One can see that anything that affects the concepts of motion greatly affects the physical theory, since one of the fundamentals of the physical theory is motion. Newton realized that relative motion exists in mechanics; but somehow the physicists who came after him did not believe relative motion applied to electromagnetic and optical experiment. Classical science assumed that motion in these cases implied motion with respect to the stagnant ether, and that electric currents were caused by electrons going through ether.[14]

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[13] d'Abro, pp. 143-144.

[14] This may be evidence of the corruption of a sound physical theory by persons who adopted the word but not the spirit of Newton.

When the above mentioned experiment showed that the respective velocities of magnet and circuit through the supposed ether, which of course are different in both cases, seemed to be irrelevant, classical science was in a bad position.

Confronted with these electrodynamical problems, Einstein decided that the ether concept was meaningless. D'Abro thinks that Einstein felt this way; "Would it not be simpler to adopt a more cautious attitude, deriving knowledge from experiment rather than trying to reconcile experiment with a series of a priori beliefs which for all we know might be totally erroneous?"[15] With the ether eliminated there is no absolute velocity; all velocities are relative.

Einstein's special theory makes use of the idea of relative velocities. In this theory, the laws of nature remain invariant whatever the velocity of the frame. To compensate for changes in time, length, and mass caused by high velocities, transformations are employed. If the laws are to be invariant and if the velocity is to change the space time coordinates, then it is the work of the transformations to change the space time coordinates in a manner that will allow the laws of nature to be invariant for any velocity of the frame. The velocity of light is taken to be constant. These needed transformations were discovered by Lorentz before the special theory of relativity was developed; but for Einstein the "v" that enters into

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[15] d'Abro, p. 143

Lorentz's transformations meant relative velocity of frames not velocities through ether.

From Oersted's and Faraday's experiments Maxwell derived mathematical equations that gave the structure of what he called an electromagnetic field and which solved many of the electrodynamical problems. The field represents energy and exists because a time rate of change of the electric field produces a space rate of change in the magnetic field and visa-versa. These changes spread out in space and produce a wave travelling at a certain velocity. This wave does not require an ether. It travels through empty space. Maxwell's equations are limited in that they describe only the structure of an electromagnetic field at any point in space at any instant. Maxwell's field equations are further limited in that they very probably break down for very great concentrations of energy.

From the preceding discussion, one can see that there is a direct connection between the difficulties that appeared in electrodynamics in the latter part of the nineteenth century and the advent of the field theory. There is also a connection between the development of the field theory and Einstein's special theory of relativity. Einstein says, "the theory of relativity arises from the field problems. The contradictions and inconsistencies of the old theories force us to ascribe new properties to the time-space continuum to the scene of all events in our physical world."[16]

We have viewed the way in which Einstein went beyond the physical theory as presented in classical mechanics and why he thought this departure was necessary. Einstein's theory of relativity has been given a connection with the field theory and formalism; one might wonder why the relativity theory is discussed in a presentation of the development of the physical theory. To understand Einstein's place in this discussion one must realize that Einstein was working at a time when there was great confusion in physics. Classical mechanics was crumbling and had in many ways lost touch with its physical foundations. No formal--mathematical--theory, not even Maxwell's equations, explained enough experimental facts or was well enough developed to be generally accepted as a basic theory of nature. Functional theories were talked of, but did not greatly influence the world of the physicist. Confusion arises if we try to think of Einstein as carrying on from some previous point in physical or mathematical theory. Einstein's chief service to science was that he did <u>not</u> try to support one idea. He attempted to wipe the board clean and to start all over. No one can forget completely the complexities he has been taught in the past; but Einstein had a skill for going back to basic simple concepts. He used all available knowledge as

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[16] Einstein and Infield, p. 259.

a tool to get him to a point where he could explain events as natural consequences of his major premises without ad hoc hypotheses. He was a great synthesizer. He used both physical and formal concepts. It is only in retrospect that his general theory of relativity appears as the ultimate physical theory.

Einstein noted that the velocity of light in empty space must have a standard value independent of the motion of the source or the receiver of light and that in two coordinatate systems moving uniformly, relative to one another all laws of nature are the same and one has no way of determining absolute uniform motion. These principles both had much experimental confirmation and no experimental contradiction, but they contradicted each other. One depended on a velocity being absolute and the other depended on all velocities being relative. Einstein saw that the only thing to do in this dilemma was to question the principle that made these two principles contradict each other. This culprit principle was the doctrine of the addition and subtraction of velocities based on the idea that time is absolute. Time must be regarded as relative. The discovery of the relativity of time led Einstein to the discovery of the relativity of simultaneity. This is the essential contribution of the special theory of relativity. The principle of relativity of simultaneity may be briefly described in this manner: an event that happens simultaneously with another event in the eyes of an observer in one coordinate system, will not happen simultaneously for an observer whose coordinate system is moving at a different velocity.[17]

Northrop notes that Einstein illustrates the principle of relativity of simultaneity in terms of physical objects. Einstein states that two lightning bolts striking railroad tracks two miles apart will cause flashes. The only spot where these two spatially separated flashes will seem to occur at exactly the same time is at a spot equidistant from the two flashes. Light travels at a constant speed and only when it has equal distances to travel will it indicate equal times of travel. Throughout Einstein's discussions of his special and general theory he gives examples of his concepts in terms of physical objects. All the relativity in Einstein's theories is defined in terms of clocks and rods. All of these are physical objects. Even the events of the relativity theory are given in physical terms. This is one factor that gives the relativity theory a place as a physical theory and a place in our historical definition of the physical theory. However, there is a much more basic reason why the special and general theories of relativity are physical theories. Einstein's general theory of relativity by making the laws of nature valid for any coordinate system--accelerated or not--succeeded in making matter and motion fundamental. The basic tensor equation of the general theory of relativity is the form of the laws of motion of physical objects in this universe which remains constant through all different

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[17] This concept will be dealt with at great length later in the paper.

relative gravitational and geometrical descriptions. This equation "designates how the absolute motion of a given mass is controlled by its absolute relation to the rest of matter."[18] To clarify the connection between making geometrical and gravitational descriptions relative and making matter and motion fundamental, the following discussion is required.

The special theory of relativity is a search for an absolute that ends with giving space-time an absolute appearance. However, space-time has a set form with the rigidity of a geometry as did the absolute space of Newton. The form of space-time introduces a prejudiced outlook in that only the nature which fits into these forms can be comprehended. Something was needed that would not impose any form on nature and that would make the laws of nature valid for any coordinate system, whatever its velocity or acceleration.[19] "Science wants its laws in such a form that they refer to nature itself and not to an arbitrarily chosen relation of nature to a reference body."[20]

Different velocities, as the special theory of relativity pointed out, give coordinate systems different metrics. If no change is made, the laws of nature are different for

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18 Northrop, p. 91.

19 An accelerated system was not handled by the special theory. If a system were accelerated, the laws of nature would not be invariant according to the special theory.

20 Northrop, p. 77.

different velocities. The special theory negates the effect of changing velocities by employing laws of transformation that allow the laws of nature to remain invariant whatever the metrics.

Different accelerations or different gravitational potentials that cause different accelerations must also lose their power to make the laws of nature different for different systems if we are to have absolute laws of nature. Einstein supplied the theory that was needed in order to make the laws of nature apply to accelerated systems. His general theory of relativity developed an equation ($G_{ik} -1/2\, g_{ik} G = T_{ik}$)[21] which made the laws of nature invariant through all changes in gravitational and metrical descriptions. This equation meant that gravitational fields and geometries could be brought into or put out of existence by a suitable change in variables. Space-time is relative because its metrical properties change with a shift from one object to another as a reference or with a shift in the distribution of matter. A change in the distribution of matter changes the gravitational potentials and the metrics and acts as a prime mover. With the above tensor equation

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21 If one thinks of this equation as determining the curvature of space, then g_{ik} gives the ten different numbers which are known as the gravitational potentials, G_{ik} gives the ten different radii of curvature at each point and T_{ik} depends on densities, velocities and other properties of the gravitational field produced by ponderable masses.

in effect, the only thing that remained absolute was matter and its motion. The absolute motion of matter is controlled by its absolute relation to the rest of matter in the universe and is revealed by the tensor equation of the general theory of relativity. The general theory is in this sense the ultimate physical theory.

The part the physical theory played in physics after the development of the general theory of relativity is not clear cut and definite. Dealing with this period of the history of physics may, therefore, not add as much to a historical definition of the physical theory as have the discussions of other periods. The modern era, however, has not yet ended, and it may just be its incompleteness that makes modern ideas seem a somewhat shaky basis for definition.

The first half of the twentieth century brings with it the quantum theory and wave mechanics. Many of the problems which these topics reveal have not yet been solved and, perhaps, we have not even asked the proper questions. But since the physical theory is one of the basic ways in which man looks at nature, physical theory plays a part in twentieth century physics.

Quantum mechanics as established by Bohr was definitely a physical theory. Before Bohr, Planck postulated the idea that black bodies radiated energy in little bundles. Einstein, Planck's contemporary, after examining the photo-electric effect decided that bundles of light energy cause electrons to be knocked off a photoelectric surface.

Rutherford, by scattering alpha particles, caused events that led him to believe that the charge and mass of an atom was concentrated at one place.

Bohr synthesized the ideas of Planck, Einstein and Rutherford and proposed a new mechanics based on his concept of the chemical atom. The fact that Bohr's atom with its nucleus surrounded by electrons in certain orbits could be represented by a physical model in which a comparatively large mass was surrounded by small spheres travelling in certain orbits indicates that Bohr was thinking in terms of a physical theory. His electrons could only go in certain orbits and could only emit certain bundles of energy when they jumped from one orbit to another. These two discontinuous concepts are in keeping with the basic discontinuity associated with a physical theory.

Bohr's theory of the atom did not work for elements with large atomic numbers. It did not explain fine splitting of spectral lines; therefore, Bohr's theory began to crumble. This situation is explained by B. Hoffman in _The Strange Story of the Quantum_ as follows:

> Spectroscopic observation showed that these quantum numbers [numbers which showed fine splitting] should often not be whole numbers at all but whole numbers and a half, something the Bohr theory was unable to explain. The experimenters found they could produce anomalous Zeeman effects in which the triplets [three spectral lines grouped close together] became intricate clusters of lines defying all the arts of the Bohr theory.[22]

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[22] Banesh Hoffman, _The Strange Story of the Quantum_ (New York: Harper & Brothers, 1947), p. 66.

Heisenberg at this time made a strong plea for a mathematical theory. He said that it was the physicist's insistence upon physical models that was limiting progress. He saw physical models as unnecessary mental crutches; and expressed a desire to replace physical models with mathematical equations. Heisenberg began to develop quantum theory as a mathematical theory. Born, Jordan and Heisenberg began to build up atomic physics upon the principle of algebraic form. Multiplication of matrix, a branch of pure algebra, greatly aided them. Dirac made generalizations from which the theory of matrices could be derived as a special case.

About this time Heisenberg developed his principle of indeterminism, which weakened his mathematical theory. This principle declared that the position and velocity of an electron can never be known exactly at the same time. This is true because the detector of position upsets the electron's velocity. Heisenberg, in the principle of uncertainty (indeterminism), is talking about the electron as an isolated physical entity, and his mathematical theory allows for consideration only of mathematical formulae and the immediately observed object. Electrons fall into neither of these categories. Electrons, which can be detected by physical means, do not fit into Heisenberg's mathematical theory. By stating his principle of indeterminism, Heisenberg is talking in terms of a physical theory. Reichenbach agrees that the principle of indeterminism is empirical and says:

> If the basic principles of quantum mechanics are correct, the principle of indeterminism must hold because it is a logical consequence of these basic principles. . . Now these principles are, of course, empirical principles, and no physicist claims absolute truth for them. But what can be claimed for them is the truth of a well established theory.[23]

The physical theory had run into trouble explaining certain parts of quantum physics, but the mathematical theory ran into difficulty in this same area. The quantum theory seemed to require both theories of nature.

L. De Broglie in 1924 introduced a hypothesis "that material particles should exhibit a dual character, that of a wave and that of a corpuscle"[24] De Broglie said that he felt there was reason to suppose the existence in a wave of points where energy was concentrated. He thought that knowledge of the laws regulating the motion of these points was equivalent to knowledge of the laws regulating the displacement of the wave since the two (wave and point) were intimately connected. De Broglie also said that, conversely, a particle could be thought of as being accompanied by a wave. Davisson and Germer working in Bell Telephone laboratories in New York in 1921 gave experimental evidence for the idea that matter has a wave aspect. Quite accidentally

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[23] Hans Reichenbach, <u>Philosophic Foundations of Quantum Mechanics</u> (Los Angeles: University of California Press, 1948), p. 13.

[24] Henry Semat, <u>Introduction to Atomic and Nuclear Physics</u> (3rd ed.; New York: Rinehart & Company, Inc., 1958), p. 171.

they overheated a lump of nickel. This treatment made the nickel crystals capable of acting as a diffraction grating for electrons--material particles. The diffraction pattern obtained resembled an X-ray diffraction pattern. These events brought to science a new topic called wave mechanics. The connection between wave mechanics and the physical theory is so much debated that this topic does not greatly assist our task of giving a historical definition of the physical theory. Hoffman reveals the unsettled air of the era which heralded the advent of wave mechanics by calling it, "a boiling maelstrom of outlandish ideas."[25] Naturally, physical theory sees the wave aspect of matter as secondary to the particle aspect. A physical theory with its emphasis on matter and particles sees the wave aspect of matter as the probability of finding a particle at a certain point. As Reichenbach says, "As to the waves the struggle between the two interpretations, therefore, amounts to the question whether the waves have thing-character or behavior-character, i.e., whether they constitute the ultimate objects of the physical world or only express the statistical behavior of such objects, the latter being represented by atomic particles."[26]

Schrödinger in generalizing De Broglie's ideas, went beyond the physical interpretation and developed wave mechanics

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[25] Hoffman, p. 71.

[26] Reichenbach, p. 22.

in a form some would call predominately mathematical.

Einstein, Planck and Bohm[27] did not like the uncertainty brought on by indeterminism and certain aspects of wave mechanics. They all seemed to be searching for an adequate physical theory and for the determinism and absolute laws that can come from a physical theory. The skepticism concerning indeterminism led Bohm to attempt to construct a "sub-quantum mechanical level." The workings of this level are to have a physical significance and definite determinate laws. Bohm says that our quantum theory and principle of indeterminism can only explain the workings of these levels roughly, because they are gross tools.

The physical theory has become involved in very recent physics, and thus added to its character. This addition made by Bohm in the early 1950's needs to be included in a historical definition of the physical theory because it reveals the strong undebatable connection of the physical theory with determinism, and because it shows the incompatability of the physical theory with intellectual dead ends. The physical theory appeared again in the early 1950's because there was so much talk of nature forever remaining a mysterious game of chance. Bohm has not, of course, been able to establish conclusively the idea of "sub-quantum mechanics." The whole idea may be metaphysical nonsense. At least, Bohm and his physical theory are doing something

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27 A twentieth century physicist noted for his work in sub-quantum mechanics.

about a challenging intellectual puzzle instead of sitting back and saying that the microscopic world will forever remain a mystery. History shows that many "mysteries" are merely problems that need to be solved.

The preceding historical definition of the physical theory of nature reveals the manner in which a theory of nature is never static or complete. The logical implications are explored more thoroughly by each successive generation. As time goes on, more minds and more machines are available to explore the possibilities of a theory. In a sense, a theory of nature is always changing. The physical theory, or any other theory of nature, however, is only as fertile as its basic premises. The basic premises do not change. If at any time they do not allow explanation of current phenomena, the whole theory must be put aside. A historical definition gives an individual the opportunity to see if a theory of nature has explained known facts, given a logically satisfying synthesis of knowledge and left room for further development. As was indicated in the introduction, one needs to know these facts about a theory of nature before he can utilize theories of nature in forming a philosophy of physics.

Specific Concepts in Physics as Described by the Physical Theory

Each theory of nature, including the physical theory, presents the concepts used in physics in a characteristic manner. Discontinuity is a fundamental distinctive characteristic of a physical interpretation of nature. This does not mean that there is no continuity associated with the physical theory. This means that persons using physical theory interpretations think in terms of particles and discontinuities. To be sure, these same persons find continuous functions in mathematics of invaluable service. Throughout the history of the physical theory, we find men striving to express discontinuous ideas in continuous mathematical terms. There is a good explanation for this two-fold aspect of the physical theory. We have seen that the physical theory is the theory of all persons who are beginning investigation. It is the first theory that comes into use in the history of science or in the history of a particular problem. The aspect of the physical theory which recommends it for beginners is that it enables people to think in terms of discrete, discontinuous particles. Its world view is one where discontinuity is the basic reality. Continuity comes into the character of the physical theory when, after thinking about the world, the physical theoretist wishes to express and manipulate his ideas about the world. It is easier to think in terms of discontinuities, but continuous mathematical functions are easier to develop and to manipulate and they are capable of handling more cases than are discontinuous functions. The beginner needs to use the easier methods of thought and expression if he is to start to investigate an entirely new field. This is the chief reason that the physical theory which views the world as discontinuous must include a place for continuity of expression. Physical theory concepts are very often represented by models or pictures.

The word model is not a completely definite term. Braithwaite says that a model and a theory are deductive systems with different interpretations of the same calculus. He declares, "in the model the logically prior premises determine the meaning of the terms occuring in the representation in the calculus of the conclusions, in the theory the logically posterior consequences determine the meaning of the theoretical terms occuring in the representation in the calculus of the premises."[28] Though the word model is admittedly vague, Braithwaite and others agree that a model is some convenient way of representing an intricate idea. Whether in the picture or calculus form a model enables one to think in a step-by-step process with the first step being the first fact one would normally discover rather than the last.

Physical theory presentation of concepts in physics may be most clearly explained by examining past interpretations. In these illustrations the characteristic treatment of the physical theory will be revealed.

The electron of the physical theory has been thought of as a small hard particle which circulates around a nucleus. There is considerable evidence for picturing the electron in these corpuscular terms. It has been found that the electron has a definite charge. This was done by the

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[28] R. B. Braithwaite, p. 90.

Millikan oil drop experiment. In this experiment two major forces act on a charged oil drop. These forces are the force due to gravity and the force due to an electric field. Various charges are put on the oil drops by friction as they go through an atomizer that sprays them into a small hole, and thus into the electric field. Theoretically one could balance the force due to the electric field and the force due to gravity by adjusting voltage. The two symbolic representations of these two forces could then be equated. The symbolic description of the electrical force includes the expression for the charge on the oil drop and all other terms in the two expressions are known from the Millikan experiment. The lowest common denominator of all the charges found in a series of experiments is the charge on an electron.[29]

The electron also has a definite mass which can be measured by an experiment with a cathode ray tube. In this experiment an electric and a magnetic field are made equal so that one is able to equate the field expressions. The experimenter wishes to make the electron beam exhibit this equality of forces by making it go in a straight line. When the straight line is perceived by noting that the electrons hit a spot in the center of a zinc sulfide covered screen,

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29 The Millikan experiment actually works with rates of fall rather than adjustments of voltages; however a detailed description is unnecessary.

the forces on each electron are known to be equal. The equation expressing the equality of the two forces is:

$$Ee = Bve \quad (1)$$

In this equation "E" represents the intensity of the electric field. The charge on the electron is designated by "e", and "B" represents the magnetic field intensity. Since this expression does not contain an expression for the mass, another step is required. The electric field is then turned off and because of the magnetic field the electrons make a circle of a definite radius on the face of the magnet. When the electric field is turned off the expression for the magnetic field intensity is expressed by the equation:

$$Bve = \frac{mv^2}{R} \quad (2)$$

In this equation "B", "v", and "e" have their previous meaning, "R" is the radius of the circle the electrons make on the face of the magnet, and "m" represents the mass of the electron. This equation is solved for "v", and the equivalent of "v" is substituted in equation (1). Equation (1) can then be solved for the ratio "$\frac{e}{m}$" in terms of the measurable quantities "E", "B", and "R". Knowing this ratio and the charge the mass can be determined.[30]

Further evidence for the physical electron was the fact that it leaves tracks. Like other charged particles,

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[30] Francis Sears and Mark Zemansky, University Physics (2nd ed.; Reading Mass.: Addison-Wesley Publishing Company, Inc., 1955), p. 566.

electrons leave streaks of droplets in a Wilson cloud chamber. These streaks show the path of the electron. Since the paths can be easily photographed and studied, one would naturally assume that they were real evidence for regarding the electron as a physical corpuscle. "It is difficult to conceive how a wave, uncollimated and free to spread in space, could make narrow tracks such as those observed in a cloud chamber."[31]

The physical theory's concept of the electron, as can be seen, had and still has much experimental support. However, much has happened since Bohr proposed an atom similar to the solar system with the nucleus taking the part of the sun and the electrons taking the part of the planets. Since that time even the physical theory's electron has become less definite. Bohr's concept of Keplerian orbits is still useful for instructive purposes, but it is actually a background upon which we superimpose fine spectral line splitting which is not explained by the Bohr theory. There are certain experiments, like the diffraction of electrons as performed by Davisson and Germer, which can not be explained by a physical model of the electron as a corpuscle without considerable ad hoc hypotheses.

We have a situation at present in which we use any theory--mathematical, physical or functional--to explain a given phenomenon. This attitude is pragmatically worthwhile;

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[31] Henry Margenau, The Nature of Physical Reality (New York: McGraw-Hill Book Company, Inc., 1950), p. 318.

but it raises havoc with logic. We have persons explaining diffraction of electrons in physical terms and spinning of electrons in mathematical terms. In short, no model in its present form explains satisfactorily all the characteristics of the functioning entity we call an electron.

We have seen the physical theory's electron as a famous being known only by reputation. The early works of Heisenberg would call the physical theory's electron an unjustified image, and Northrop would answer:

> The desire for physical models does not have its basis, as so many of our contemporary scientists assume, in the perverse tendency of the human mind to think in terms of images, but in the rationale of all modern and contemporary experimental scientific procedure.[32]

Perhaps what we designate as an electron is better explained by a mathematical equation; but the success of the past physical concepts of the electron leaves hope that on the sub-quantum level, as Bohm[33] calls it, the electron can be seen again in terms of matter and motion.

Perhaps a more definite physical concept is simultaneity. Simultaneity for many years was thought to be absolute. Not until Einstein's work with the relativity theory did the notion of relative simultaneity have significance. Einstein explained relative simultaneity in terms of physical objects.

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[32] Northrop, p. 131.

[33] Bohm is the contemporary physicist whose theory on sub-quantum mechanics was discussed previously.

The absolute theory of time upon which the absolute theory of simultaneity is based regards time as an endless series of non-intersecting lines. There could only be one such series in nature; therefore, if an observer in one frame of reference read his clocks correctly and designated that two events happen at the same instant in this series, observers in every other frame of reference reading correctly will assign the same two events to the same instant.

The theory of relative simultaneity as described by Einstein in physical terms makes the relativity of simultaneity between spatially separated events dependent on the observer's frame of reference. Einstein gives a physical example to illustrate relative simultaneity. He uses a coordinate system in the shape of a box car as the scene of his illustration. This system is moving at high velocities and there is a light in the center of it. Einstein shows that an inside observer, who is moving with the coordinate system of the box car will see the light signals sent out by the light in the center of the box car hit the walls simultaneously. An outside observer who is located on the perpendicular bisector of the box car would say, "One of the walls is trying to escape from and the opposite wall to approach the light signal. Therefore, the escaping wall will be met by the signal a little later than the approaching one."[34] The relativity of time makes only

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[34] Einstein and Infield, p. 188.

a slight difference in the observations of inside and outside observers if the velocity of the coordinate system is small compared to the velocity of light; but there is a difference. The ordinary objects in our experience are moving so slowly compared to the velocity of light that we can not possibly detect the difference that the "outside" observer detected. In our world the light signal would reach the sides of the car so soon that the "escaping"-"approaching" factors would have no detectable effect. The impossiblity of detecting relative simultaneity in ordinary events involving ordinary objects is responsible for mankind's clinging so tenaciously to absolute time and absolute simultaneity.

The concept of relative simultaneity is one of the chief contributions of the special theory of relativity. Here we have seen the characteristic manner in which the physical theory presents this concept. We have also discovered that the man who developed the theory of relative simultaneity presented it in physical terms. The story, however, is not finished. The functional theory has a different view of this same concept as we shall see.

One crucial concept used in physics, which the physical theory presents in a characteristic manner, is measurement. In order to measure, we must first have a standard and an agreed method of measuring. The standard for Euclidian measurements is a straight rigid rod. The rod must be straight so that it can be duplicated easily, and it must be rigid so that no matter where it is displaced, it will maintain its shape and size. The standard must maintain its shape and size because we want all our measurements to be correlated; otherwise, we could use a rubber band as a standard. A physical definition for straightness is given by d'Abro. He says: "Two rods would be recognized as straight if after coinciding when placed lengthwise they continued to coincide when one rod was turned over on itself."[35] The process needed for measurement seems to be defined by stating that we lay the rod end to end in a straight line between two points if we wish to obtain the shortest distance between these two points.

It requires a geometry, however, to give a definition of "straight", and thereby of shortest distance. A geometry also gives a definition of congruence, which is needed if we are to be sure that the rod and its substitutes really cover the same length. Euclidian geometry defines a straight line as the shortest distance between two points. The "shortest distance" between two points, however, changes with changing geometries. A line curved in terms of Euclidian geometry may be the "shortest distance" between two points in a non-Euclidian geometry. The Euclidian definition of a straight line depends on Euclid's <u>Parallel Postulate</u>, which states that through a point in a plane it is always possible to draw one and only one straight line parallel to a given straight line lying in the plane. His definition

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[35] d'Abro, p. 34.

applies only in a three dimensional continuum. Euclid's definition of congruence is dependent on his Parallel Postulate. Riemann and Lobatchewski, who did not accept Euclid's Parallel Postulate, would obviously derive a different meaning for straightness and a different meaning for congruence.

There is no absolute geometry. Geometries are idealizations from the physical world, and an object in the physical world changes properties if it is going very fast or if it is accelerating. For example physical rods actually shorten at high speeds. Euclid's geometry went one step beyond the empirical stage where straightness was defined in terms of two physical rods. He could not appeal to empirical definitions, for he wanted perfect rigor. He wanted an exact definition of a straight line and of the equality of two distant spaces. Euclid, therefore, had to employ indirect methods. He posited axioms and postulates in order to state in an accurate way the properties that appeared in physical objects only in an approximate way.

> Euclid's geometry was thus the geometry of perfectly rigid bodies, which, though idealized copies of the bodies commonly regarded as rigid in the world of experience, were yet defined in such a manner to be untainted by the inaccuracies attendant on all physical measurements.[36]

One can see that geometry in its origin was physical and was concerned with possible depositions of objects on this earth. Geometry progressed to a point where it dealt with

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[36] d'Abro, p. 35.

postulates and axioms rather than physical objects, but its origin was physical. If this realization had been prevalent when Einstein presented his theory describing what would happen in a world which was travelling at high speed or accelerating, no one would have seen relativity as an astounding refutation of an absolute truth--i.e. of Euclidian geometry. They would have realized that relativity physics requires a different geometry because it is dealing with other than ordinary physical situations. In any case, we have seen that a geometry is necessary to give meaning to directions given in the method of measurement, and that geometries as well as standards have physical meaning.

With the advent of Einstein's special theory of relativity, time became important. Measurements were made in a four dimensional continuum of space-time. Einstein's theory required two standards for measurement--a rod and a clock. The geometry that dictated straightness and congruence in this case had to be different from Euclidian geometry. Even the standard rod would perform a different task in a world where relativity effects were evident. The rod would change length as it changed velocity.

Gamow discusses the deformation of a physical standard rod due to acceleration by picturing a person measuring the shortest distance between two points on the periphery of a rotating platform. He points out that due to the rotation of the platform, the measuring sticks will suffer a relativistic contraction, and those of them which are closer to the periphery of the platform will be contracted more than those located nearer to the center. It is clear that in this illustration in order to get the most distance covered by each stick, one should place it as near to the center as possible. However, both ends of the line to be measured are fixed on the periphery; it will therefore be *better when the platform is still not to move the sticks* from the middle of the line connecting the two periphery points too close to the center. The shortest distance between the two points under the above conditions with the platform rotating is a curve slightly convex toward the center.[37] Obviously a different geometry is needed in an accelerated system if we are to retain rods and clocks as standards.

In what kind of a geometry would the shortest distance between two points be a curve, and consequently would the sum of the angles in a triangle be smaller than two right angles? A geometry that would perform these tasks was needed by relativistic physics. It happened that, before Einstein's theory of relativity was developed, a mathematician had developed a geometry in which space would be curved (relative to a Euclidian world), in which the sum of the angles of a triangle would be less than one hundred and eighty degrees, and in which the Euclidian Parallel Postulate was replaced by a postulate saying that an indefinite number of nonintersecting straight lines could be drawn through a point in a plane parallel to a given straight line in

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[37] G. Gamow, Mr. Tompkins in Wonderland (New York: The Macmillan Company, 1945), p. 68.

the plane. This was an adequate geometry for Einsteinian physics. Although this Lobatchewskian geometry was developed without the aid of physical experiment, it has a definite meaning in physical terms as we have seen in the rotating platform illustration. We have seen that an acceleration caused the deformation of a standard, and caused the shortest distance between two points to be a curved line (if referred to a Euclidian world). Since any gravitational field is equivalent to an acceleration and since one mass causes another to accelerate, in physical terms "curvature" of space is caused by physical matter.

This discussion has taken us away from the meter stick and the Euclidian geometry of the freshman laboratory; but it has served to indicate that there is no absolute geometry and that the same standard acts differently under different physical conditions. Standards change in physical characteristics with changes in the velocity, and at different velocities a standard will be deformed in different degrees; however a standard rod--or rod and clock--is always essential to measurement. Different geometries apply in different physical cases and because of this, congruence, straightness, and "shortest distance" between two points changes meaning with changing physical conditions. Congruence, straightness, and "shortest distance" must be defined if measurement is to be definite. Since these meanings depend indirectly on the physical situation, one must specify his standard, his method <u>and</u> his physical situation in order to compare measurements. In ordinary measurement, we shall not be concerned with the changes wrought by acceleration and high speed; but we must realize the nature and the physical aspects of our assumptions if we are to avoid errors caused by letting our assumptions slip into the status of facts.

The following historical definition of the mathematical theory of nature with the subsequent discussion of characteristic mathematical theory interpretations of concepts used in physics will, I hope give a fuller meaning to both the mathematical theory and the physical theory. These two theories view the history of physics in different ways. If these views are contrasted, both theories are seen in a broader more meaningful light, and thus they become better tools for developing an individual philosophy.

CHAPTER II

THE MATHEMATICAL THEORY OF NATURE

An Historical Definition of the Mathematical Theory of Nature

The mathematical theory of nature takes form as the basic entity in the universe. All laws of nature are stated by the mathematical theory in terms of some type of form--usually a geometry or a mathematical equation. The mathematical theory is more closely associated with continuity than is the physical theory. The physical theory only uses continuity in its expression of its knowledge of nature. The mathematical theory proposes that continuity is a fundamental feature of nature herself. The mathematical theory not only uses continuous functions as tools of expression, but it views nature as a vast rational continuity which exhibits certain forms to her observers. The mathematical theory and the physical theory may use the same types of continuous mathematical functions in manipulating and communicating their knowledge of nature; however nature is made up of physical discrete discontinuous particles in the physical theory, and nature is made up of rational forms which exhibit continuity in the mathematical theory. An historical definition of the mathematical theory will, of course, cover some of the same events that were covered while defining the physical theory; but in these two discussions there is a marked difference in outlook.

After the Greeks had investigated the possibilities of the physical theory to some degree, Greek science slowly became concerned predominately with mathematics and astronomy. In Greek science there is a definite sense that mathematics and astronomy are purer and finer than other forms of thought. Because mathematics deals with abstractions and symbols, and astronomy deals with the far-away, these two disciplines have historically been thought of as untainted by man's subjective and earthly smallness. Indeed, mathematics and astronomy dominated Greek science.

Anaximander was one of the first Greeks to be impressed by the endless continuity physical nature reveals. This observation suggests the advent of a mathematical theory; for, as we have seen, a mathematical theory sees nature as possessing continuity. This realization led Anaximander to formulate the concept of the "Boundless". He regarded the "Boundless" as physical. Pythagoras believed that there is a balance in nature; he saw this balance in music. Pythagoras thought that in nature the "Boundless" was balanced by the "Limit". The concept of the "Limit" was a vague idea; it had no specific qualities, and therefore was not of much use to science. The concept of the "Limit" could even hinder science, since any difficult problem could be seen as a manifestation of the "Limit" and be forgotten.

Pythagoras, however, made a startling discovery; he found that in music the equilibrium--balance--could be expressed arithmetically without bringing in the "Boundless" or the "Limit". It was, consequently, the relation between "Boundless" and "Limit" that could be expressed and not the entities themselves. Facts could be discussed by using numbers without knowing the meaning of the facts. "It suddenly dawned upon the Pythagorean mind that this universe is in some sense essentially numerical and mathematical."[1] Pythagoras, consequently, professed the idea that the real is number. He also formulated the relation of the hypotenuse of a right triangle to its two sides and laid the foundation of number theory. The mathematical theory had made its first appearance. Some of the logical consequences of making form basic had been discovered and the history of the mathematical theory, which is responsible for its present meaning, had begun.

After Pythagoras, the Greeks continued to view form as all important. Many different geometrical principles were presented. Finally Euclid put known geometrical principles into a specific deductive form. Although Euclidian geometry deals with idealized properties of physical objects, many people have seen Euclidian geometry as an absolute logical continuity dealing with absolute abstract forms. To persons who stress the formal aspect of Euclidian geometry a geometrical circle is not just an idealized picture of something they can feel, touch and see, but it is an abstract perfection, existing in the absolute--or the Mind of God. Exdoxos,

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[1] Northrop, p. 13.

a Greek astronomer, gave the mathematical theory a definite and strong position in astronomy. He gathered astronomical observations of his predecessors and his contemporaries and put them together in a systematic mathematical astronomy. The laws of Eudoxos, that made possible accurate prediction of events in astronomy did not mention physical objects; they were concerned with perfect geometrical forms. Since mathematics has always been an indispensible aid to astronomy, it is not surprising that the mathematical theory played an important part in astronomy. "Thus the ideal purely conceptual categories of mathematics and logic were revealed as constituting the very essence of the entire astronomical universe in which we live."[2] The mathematical theory through its connection with astronomy gained a fuller meaning.

A man who contributed perhaps more than any other before or since to the meaning of the mathematical theory of nature is Plato. Plato was essentially a philosopher; but he has a definite place in this objective, factual history of the mathematical theory. At the outset we decided that a theory of nature is a specific logical process whose results can be confirmed as logical or illogical by a group of rational persons who accept its basic premises. Plato did a great deal to explore the logical consequences of making formal and mathematical categories fundamental, and therefore helped develop the mathematical theory.

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[2] Northrop, p. 14.

Plato declared that the real is rational as opposed to the physical theory that the real is physical. This idea, for Plato, was based on carefully thought out mathematical concepts and verified evidence from astronomy. It was not merely opinion. (The great importance of mathematics to Plato can be understood if one realizes that his individual philosophy rested on an understanding of mathematics.) After Plato's work, certain consequences of the mathematical theory of nature became clear. One consequence was that mathematical formal theory needed mathematics to make its objective laws clear. Since logical structure was (for the mathematical theory) basic in nature, logic's shorthand-mathematics was essential. A second consequence that became clear concerned epistemology--the science of knowing. The world which is so important to the physical theory--the world of sensation--is mere illusion to the mathematical theory. If the ultimate entity in nature is rational and formal, the only way to know reality is to reason. Experiment is only useful because it suggests certain ways of thinking. A further consequence of Plato's dealings with the mathematical theory is that mathematical theory thereafter indicated a characteristic method for discovering reality. Since one can not depend on experiment to reveal the real world, he has to develop a system in which experiment is not crucial. Plato's system was the method of hypothesis. He used observations only to indicate possible mathematical forms in nature. The method of hypothesis commits the logical fallacy of proving what is first stated; therefore

Plato needed to embellish his method with dialectic--the process of tracing all hypotheses to their common presuppositions and putting them together in a deductive system.

The Greeks had not developed experimental technique; therefore it is not surprising that a theory which did not depend on experimental evidence was the successful theory of nature in the Golden Age of Greece. The mathematical theory got a very good start in the Golden Age. Some of the best minds in one of the most fruitful intellectual ages worked to develop this theory. It also had a well developed mathematics and a successful astronomy upon which to build.

The spirit of Plato and his mathematical theory prevailed for centuries after his death. Some contemporary physicists still believe the mathematical theory to be the valid theory of nature. Sir James Jeans says, "In brief nature is rational."[3] In this same passage in Physics and Philosophy Jeans uses the Poincare image of the facts of science as a heap of stones and the deductive system as the house made from the stones and he says by way of illustration.

> "In physics the separate stones are numbers and the features of the house are relations between large groups of numbers. Clearly these relations will be most easily recorded and explained by embodying them in mathematical formulae, so that our scientific house will consist of a collection of mathematical

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[3] Sir James Jeans, Physics and Philosophy (Cambridge: University Press, 1943), p. 8.

> formulae, in this way and this alone, can we express the pattern of events."[4]

This sounds like Plato speaking again in the modern world.

This quotation and the whole historical definition of the mathematical theory points out a sharp distinction between the mathematical and physical theories. The physical theory during its historical definition seemed always to be adding a new concept and developing a new character. On the other hand, the mathematical theory, while developing to a certain degree, seems to return periodically to exactly the position of the Greeks. This difference has a very logical explanation. The physical theory declares that matter and motion are basic in nature. This leads to experiments with physical matter and motion to find out about reality. As equipment becomes more refined and records are kept more accurately, one scientist can use the work of generations of scientists, and thereby has <u>time</u> to find new relationships. He, thus, helps to give physical theory an added or revised meaning. The mathematical theory declares that form is basic. Nature therefore, contains an essential logic and a changelessness which can be seen only through reasoning. Since reasoning is the only way to discover reality according to the mathematical theory, every man has to go separately through all the logic of his predecessors before he can begin to discuss

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[4] <u>Ibid.</u>

reality. The individual is rare who has time to go beyond the reasoning of the Greeks.

The mind of individual man has not developed since the time of the Greeks in the manner in which machines for experimenting have developed. Since the mathematical theoretician of modern times is using the same tool--a human mind--as his Greek predecessors, there is small wonder that he often arrives at the same solution. The modern mathematical theoretician is also looking for a changeless feature and might feel before he starts that he will arrive at established conclusions. Physical experiments become for him unreliable. The mathematical theory can be maintained without adding to its meaning in the face of facts it finds hard to explain because these facts can be dismissed as sensory illusions.

This does not mean that the mathematical theory has not contributed originality to science. It means that the originalities appear as stepping stones in a process of returning to a changeless form.

The spirit of Plato over-shadowed the Middle Ages. It was not just the success of the mathematical theory in astronomy nor its compatibility with logically convincing geometries which gave it the power to affect the thinking of persons who lived centuries after the Greeks. One of the fundamental reasons for the ascendency of the mathematical theory in the period directly following Plato and in the Middle Ages is that it lends itself to authoritarian forms. It can, thus, be carried from age to age unchanged as part of inherited knowledge. This is one distinctive feature of the mathematical theory that is revealed by an historical definition.

The mathematical theory emphasizes the importance of reasoning. Man has a tendency to trust his own reasoning far less than he trusts his own experimental results. Defying convention has always been easier to accomplish in the form of publishing experimental data than in the form of speaking out against convention using oneself as an authority. When pure reason is the criterior for right and wrong, man has historically assumed that the person who has done more work in the field, who is more noted or who has written more books in the field has the best reason behind him. In short, the authority's reason is trusted.

Although Plato would not have wished it, science went into eclipse when the Platonic mathematical theory became the supreme theory of nature. When the importances of the physical world of sensation is denied, it is not long before concern with nature for its own sake disappears. When, during the Middle Ages, empirical science lost its importance, the doom of mathematics was foreshadowed.[5] An interest in mathematics comes to man while he is looking for a simpler way in which to express the relations in the world around him. When he loses interest in the world

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[5] Northrop, p. 28.

around him, he soon loses interest in mathematics. Thus, the acceptance of the mathematical theory defeated the growth of mathematics.

The mathematical theory's emphasis on reason led finally to a state where individuals were searching for the all prevailing form within themselves and to a state where individuals were contemplating other worlds. This trend toward inner contemplation was a serious injury to scientific investigation.

In the Catholic Church of the Middle Ages the mathematical theory of nature found a perfect companion. The Church was the main power during the Middle Ages, and thus the mathematical theory prevailed. Because the mathematical theory lends itself to authoritarian forms, it found a useful place in the authoritarian form of the Catholic Church. The emphasis on reason seen in the mathematical theory led its followers to introspection and a concern with other worldiness. This aspect of the mathematical theory helped make it compatible with the teachings of the Church. The teachings of the Catholic Church saw life as but a moment of suffering before man was allowed to slip into another more beautiful world where all would be made well and clear. In a sense, the Christian heaven was the place where the ultimate form of the mathematical theory would be revealed. The Christian emphasis on the importance to God of each individual is compatible with the search for reality within oneself which is an outcome of the mathematical theory.

Naturally the mathematical theory had become stagnant by the time of Galileo. Since no essential change in the way of looking at the universe had occured for centuries, this is not surprising. Authoritarian dominated eras like the Middle Ages do not usually produce radical changes of any kind. Ironically it was Thomas Aquinas, the great Catholic theologian, who opened the way for rebirth of science. By emphasizing the Aristotelian or functional theory of nature, Aquinas emphasized the importance of observing the real physical world. This resulted from the fact that the functional theory looked to nature instead of to reason for reality. Later we shall discuss the functional theory in full and the importance of observation of nature to the functional theory will be made clear. At present we need say only that Aristotle became interested in the principle of becoming--in the idea that the real changes its properties--by studying biological phenomena. If the real changes its properties, we must continually watch it to remain in touch with reality. This was the theory that Aquinas revived. The return to an interest in nature for nature's sake, which had the authority of the Catholic Church behind it, was more directly responsible for the rebirth of the physical theory than was the work of individual intellectual rebels who labored to revive science. The seeds of the destruction of the absolute power of the Catholic Church were planted by one of its chief saints in the same way that the seeds of the destruction of the mathematical theory were planted by the theory itself.

Galileo's work has been discussed in full, and one can immediately realize that Galileo's concern with physical terrestrial objects was incompatible with the reason-oriented mathematical theory. Perhaps if Galileo had been unsuccessful and had failed to correlate natural phenomena, there would have been an immediate return to mathematical theory. Galileo, however, was successful and the mathematical theory of nature declined rapidly.

As time progressed, the physical theory was able to explain more and more phenomena. It explained the near-at-hand phenomena, then after Newton's work it explained the far-away phenomena. Man was given a systematic statement of the workings of the universe by Newton in the form of mechanics which he based on his three laws of motion. Man was also given power to predict with remarkable accuracy the workings of macroscopic nature. With this power to predict came a limited power to control. The sufferings during life no longer needed to be considered as insignificant events necessary for a fuller understanding of reality. The return of the physical theory led away from things of the mind to things of the body. After the seventeenth century the physical side of life had again become important and a limited ability to control nature to man's advantage was developed. Science's ability to make a better material life for man has been the one feature of science that has consistently captured popular support for science. After

Newton, the physical theory ascended to dominance on a wave of popular support.[6]

The mathematical theory did not die out completely and then suddenly reappear in the latter nineteenth century. A few minds were always working out mathematical relationships in nature and viewing nature as basically mathematical. Galileo, Newton, and those who followed consistently emphasized the quantitative nature of physical theory, but their terms, although predominantly physical, were stated in mathematical terms. Newton, Gauss, Euler, and others found it necessary to develop new mathematical forms with which to describe quantitative physical chimera. Descartes, a contemporary of Newton's, attempted to bring all the phenomena of physics within a single system. His system unlike Newton's was kinematical--to do with motion--and was mostly in error. It is interesting to note, however, that he said, "I do not accept any other principles in physics than there are in geometry and abstract mathematics because all the phenomena of nature may be explained by their means."[7]

In the latter part of the nineteenth century it became evident that nature might well exhibit continuity as its basic feature. Theories which took the basic entities in nature to be discontinuous ran into difficulties explaining

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[6] Ibid., p. 37.

[7] Jeans, p. 107.

optical and electrical phenomena. Slowly the idea of waves and fields became accepted. These ideas revealed and acceptance of the mathematical theory idea that nature has continuity as a basic feature. Classical physicists of the nineteenth century had long been expressing their knowledge of nature in continuous terms and for the most part they thought in continuous terms. But the continuity that the classical physicist attributed to nature was a physical rather than a rational continuity. These men did not expound either the mathematical or the physical theory. This was a transition era. They had progressed from the point where nature is described as discontinuous particles, but they had not been able to free themselves from the idea that nature is physical. The existence of the ether concept which dominated the latter nineteenth century is evidence that physics was in a transitional period. The ether was a physical medium which exhibited stresses and strains, but it was not made up of discrete particles. One could not touch, feel or handle the ether. It exhibited continuity, but it was not the rational continuity of a strictly mathematical theory. It was the continuity of a physical stream which flows and twists.

A person using a completely physical theory on the lowest level where it first appears describes and thinks of nature in only physical discontinuous terms. Nature is described as being made up of objects one can touch, see and handle. A person using a completely mathematical theory as it appears on the most sophisticated refined level describes and thinks of nature only in rational continuous terms. Nature here does not lend itself to models of any kind. As the physical theory progresses toward the mathematical theory we find that nature is seen as less and less discontinuous and more and more continuous. Nature is also seen as less and less physical and more and more rational. The period which we are about to discuss is one of transition. We will see the development of the meaning of the mathematical theory most clearly if we show how in this period (the latter nineteenth century) the continuous models gained acceptance over the discontinuous models and how there was a trend toward the rational explanation at the expense of the physical explanation.

In optics there was a struggle between the wave and the particle theory of light. This indicated that a transition was occuring. The physical theory model of light as corpuscular was being replaced by the mathematical theory idea of light as a continuous wave. These waves had, in many cases, physical characteristics. They were not yet completely rational, mathematical functions, but they did exhibit the continuity which only mathematical theories attribute to the basic foundations of nature. In the nineteenth century, Huygens had given evidence for the support of the wave theory--refraction and reflection were explained readily by the wave theory. Newton's name had been afixed to the corpuscular theory, which after a fashion explained reflection, refraction and color. The corpuscular theory was at this time accepted mostly because of the general success of the physical theory to which it was adjoined. The physical theory stressing discontinuity had been very successful in explaining mechanical phenomena.

At the beginning of the nineteenth century, the wave theory of light gained support. An English experimenter named Young worked with the interference phenomenon and noticed that if light from a single source was put through two slits very close together a streak of light and a streak of dark would appear on a screen in front of the system of slits or diffraction grating. This phenomenon could be explained easily if light were assumed to be wave-like. One could say that the waves either constructively or destructively interfered. A diagram will show Young's experiment most clearly.

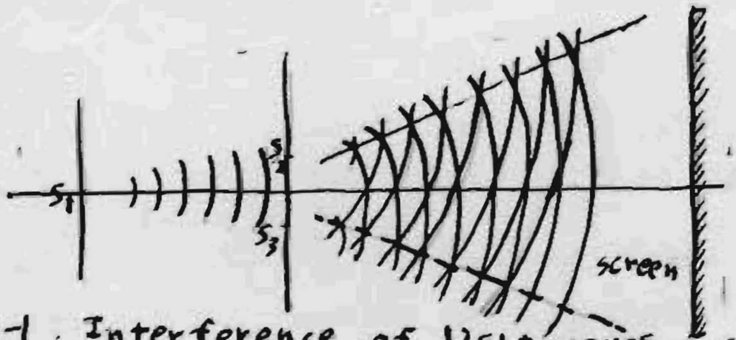

Fig 2-1. Interference of light waves passing through two slits. (After Sears + Zemansky, University Physics, p. 837.)

Young did not present a purely mathematical wave theory. His wave was not a rational function; it was a physical wave which required an ether through which to pass. Young postulated the luminiferous ether we have mentioned. It supposedly was an undetectable substance which pervaded the universe.

Even this wave theory was not generally accepted until Fresnal accepted Young's ideas and used them to explain polarization. The French academy of science did not favor the wave theory of light, but finally the success of the wave theory caused it to be generally accepted in the early nineteenth century. The continuous, mathematical aspect of the world of electricity and magnetism was brought forward due to the work of Faraday, Maxwell, and Hertz.

Because Faraday had little grasp of mathematical technique, he described the continuity he saw in electrical and magnetic phenomena as "tubes of force". Ironically it was not the mathematicians who pioneered the highly mathematical field theory. It was the unmathematical Faraday. Faraday believed that electromagnetic effects did not have their basis in lumps of iron or in physical magnets. "For him, in a real sense, nothing less than the whole universe was involved, the wires, magnets, and other material gadgets being rather insignificant incidents."[8] Here we see the de-emphasis of matter which usually accompanies the appearance of a mathematical theory. Faraday pictured a magnet or a current carrying wire as having tentacles which reach out in all directions. The tentacles were stronger nearer a material body and grew weaker at greater distances. It was these tentacles that were the ultimate reality in nature. Experimental evidence supported Faraday's idea; but these ideas were

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[8] Hoffman, p. 10.

so simple and basic that those who believed nature to be intricate ridiculed Faraday's idea.

When Clerk Maxwell began translating Faraday's private unfamiliar ideas into the language of mathematics, these concepts became more generally accepted. Strangely enough Faraday's ideas fitted perfectly into mathematical forms. Maxwell's labors produced the concept of the field. "To describe the traffic of the universe a combining set of laws was necessary."[9] The electromagnetic field can be thought of as a refined mathematical form of Faraday's tubes of force. The electromagnetic field has a physical meaning; but the field is best expressed in a mathematical form, and mathematical form was the ultimate reality of the Maxwellian era. This era is an important event in the history of the mathematical theory of nature.

The mathematical significance of Maxwell's electromagnetic field can be best grasped by a brief description of the derivation of the equations expressing this field. Maxwell found that in a region where the electric induction--a quantity proportional to the number of lines of force in a field--in a dielectric medium was changing, he could equate this change to an electric current, with which a magnet field was automatically associated. He could, then, express "relations between the time rate of change

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[9] J. R. Newman, Review of Causality and Chance, by D. Bohm, Scientific American, 198 (January, 1958), p. 111.

of the components of the electric induction and the space rate of change of the components of the associated magnetic field."[10] Maxwell, moreover, found that in a region where the magnetic induction was changing he could be sure that there existed an electric field and he could express relations "between the time rate of change of components of the magnetic induction and the space rate of change of the components of the electric intensity associated with them."[11]

The relationships which Maxwell expressed were presented in mathematical equations. He, further, was able to manipulate mathematically the two sets of relationships and to produce equations which gave the time and space relations of each component of electric intensity and the time and space relations of each component of magnetic intensity. It so happens that electric intensity admits of a wave solution. If we assume electric intensity is moving in a wave we can derive the same second order differential equation which Maxwell derived using the process which we just discussed. The only requirement for making the two equations identical is that the velocity of propagation of the wave must equal the speed of light divided by the square root of the dielectric constant times the permeability. That is, in a vacuum where the

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[10] Norman Gilbert, Electricity and Magnetism (3rd ed.; New York: The Macmillan Company, 1957), p. 458.

[11] Ibid.

dielectric constant and the permeability are one, the speed of light must equal the speed of the electromagnetic waves. The two electric intensity equations of the "x" component of electrical intensity are:

$$\frac{1}{v^2}\frac{\partial^2 E_x}{\partial t^2} = \frac{\partial^2 E_x}{\partial x^2} + \frac{\partial^2 E_x}{\partial y^2} + \frac{\partial^2 E_x}{\partial z^2}$$

$$\frac{\mu K}{c^2}\frac{\partial^2 E_x}{\partial t^2} = \frac{\partial^2 E_x}{\partial x^2} + \frac{\partial^2 E_x}{\partial y^2} + \frac{\partial^2 E_x}{\partial z^2}$$

It can be seen that these are identical if $\frac{\mu K}{C^2} = \frac{1}{V^2}$. The meaning of μ, K, C and V have been given. "E" is electric intensity, "t" is time and "x", "y" and "z" are space coordinates. The same type of reasoning applies to the magnetic intensity and two equations of the same form can be derived. Once the relation between the discovered electric and magnetic waves was seen by Maxwell, he had begun to formulate electromagnetic theory which combined light, electricity and magnetism, and he had postulated the existence of a new type of wave expressible in a mathematical equation--the electromagnetic wave. It was Hertz's destiny to demonstrate the existence of these waves.

The electromagnetic waves for which Hertz wished to find experimental evidence were thought to have two components perpendicular to one another. The electric intensity was thought to lie in one plane and the magnetic intensity in another. The waves of the two components are shown below:

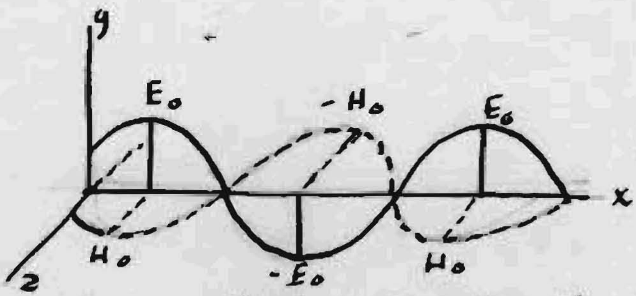

Fig 2-2, Waves of electric intensity and magnetic intensity - components of electro-magnetic wave. (After Gilbert, Electricity and Magnetism, p. 465.)

Hertz devised an oscillator of sufficiently high frequency to produce radiations of manageable wave lengths and devised a way of detecting these waves. Hertz devised an oscillator which because it contained a small inductance and a small capacitance was able to produce a sufficiently high frequency oscillation. Once a spark had jumped the spark gap in the oscillator circuit an oscillatory discharge occured--the capacitance and the inductance alternately stored energy. Apart from the oscillator, Hertz placed a detector which took the form of a loop of wire with a gap in it. When he saw electrical sparks jump across this gap he was convinced that electromagnetic waves were responsible. After all no wires connected the oscillator and the detector. Hertz proved these waves were the electromagnetic waves of Maxwellian theory by showing that the waves could be polarized, reflected and refracted. Now the continuous wave theory which is basically a mathematical theory was victorious. It had predicted a wave before the wave was known to exist. This had been done solely by work with mathematical equations. The waves that had been discovered were not physical. They could not be seen, touched or felt; yet they determined optical, electrical and magnetic effects. Their effects could be detected by the senses. Was not this evidence of a formal wave which was the basic entity in nature and which produced changes in nature?

However, the ether was still "hanging around" to keep the wave theory from being completely rational. The ether was a physical concept. Even though Lorentz, foreshadowing the relativity theory, figured out the transformations of space and time which were needed in electrodynamics, he persisted in connecting his transformation with the ether. He also was unable to give up his classical idea of the absoluteness of time even though he worked out transformations for time as well as space. Lorentz felt that there was a "real time" and that the time which changed was "local time". The ether, partly because of its artificiality, was not destined to remain for long in physics. "Taking Lorentz' theory as it stands, one cannot help but recognize that this accumulation of hypotheses postulated ad hoc makes it painfully artificial. According to the theory, the ether must be regarded as stagnant and the earth as moving through it with some definite velocity. This velocity must, however, remain eternally unknowable to us."[12]

It is not surprising in view of the preceding discussion that Einstein felt that the ether was a useless concept. We discussed the relativity theory at some length when we were historically defining the physical theory; however certain of its aspects are essential to an historical definition of the mathematical theory. We must, therefore, undertake a little repetition. We saw that with Einstein's dismissal of the ether he began to form the special theory of relativity. This theory showed that the laws of nature are invariant with respect to the velocity of a frame of reference, we noted that in the special theory, the velocity of light is constant, and that space, time and simultaneity are relative. The special theory of relativity was in many ways a mathematical theory and if Einstein had stopped with the special theory, the mathematical theory of nature might have continued to be the dominant theory.

Events in the special theory of relativity take place in space-time. Space and time coordinates depend on the velocity of the frame but space-time has a certain absoluteness. Every person who is in a different frame divides space-time up differently. This phenomenon can be demonstrated as follows: Three different persons are asked to arrive at the number twelve by multiplying two numbers. One person says four times three is twelve. One says that six times

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[12] d'Abro, p. 137.

two is twelve. Another says that twelve times one is twelve. But they all agree that the product is twelve. These persons acted as though they were in different frames of reference. The special theory, by giving space-time (a chronogeometry) absoluteness brings the mathematical theory to the foreground. This is because a formal rather than a physical category had again become the basic entity in nature. All events are placed in relation to space-time, and space-time could only be described adequately in mathematical terms.

> At this stage, relativity theory absorbed the attention of men. Its mathematical emphasis and chrono-geometrical character caused uncritical scientific minds to suppose that the continuous theory was again established. Nature is a four dimensional continuum in which an object is but a series of static event particles taken as at rest or in motion according to one's frame of references.[13]

The general theory of relativity has been logically shown to be basically a physical theory. However, since the general theory uses mathematics extensively, we should examine the connection between mathematical theory and the general theory of relativity.

The curvature of space that we have seen associated with the change in metrics produced by acceleration of matter has by some who use the mathematical theory been interpreted quite differently. These persons think that gravitational fields which produce acceleration are merely manifestations of the curvature of space. Since space can be thought of

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[13] Northrop, p. 126.

as curved and continuous and since curved space can be described in geometrical terms and described as positively or negatively curved, there is a mathematical connection between the relativity theory and the mathematical theory of nature. The same equation that we showed had vast physical significance is, nevertheless, a mathematical equation describing the universe. The g_{ik} of the equation. ($G_{ik} - \frac{1}{2} g_{ik} = T_{ik}$) represents the gravitational potential, and the curvature at each point is described by ten different radii of curvature represented by the G_{ik} of the equation. Although the equation is generally agreed to have basically a physical significance, the power of the mathematical theory is demonstrated by the fact that a mathematical equation is used to describe the laws of the universe. It could be said that the equation is basic and that the physical interpretation just plays the part of a model.

The advent of the quantum theory gave the mathematical theory further territory in which to develop. It found both success and failure.

Bohr, as we have seen, synthesized the ideas of Planck, Einstein and Rutherford and developed a quantum theory of the atom in which discontinuity ruled and in which only quanta of energy were emitted. This was a truly physical theory. However, when the Bohr theory began to have trouble explaining spectral phenomena, Heisenberg stepped in with a mathematical theory. He suggested giving up physical models and assigning mathematical equations to quantum phenomena.

In order to comprehend Heisenberg's contribution to quantum physics and to the mathematical theory of nature, one must see it as a reaction to the quantum theory of Bohr. Heisenberg wished to explain the things which seemed to defy explanation in terms of the Bohr theory.

> Had the Bohr theory no more to its credit than this, that it revealed to Heisenberg the secret of its own weakness, and thus of the innermost weakness of all previous physics, it would still go down in history as a transcendental influence in the evolution of modern science.[14]

Bohr had used Fourier analysis as the mathematical tool for his correspondence principle. Fourier declared that a sine wave has only one frequency and that all other rhythmic waves may be decomposed into constituent sine waves of different frequencies. Bohr's theory stated that the rhythm of the motion of electrons in orbit around the nucleus when subjected to Fourier analysis should show the same pure frequencies as did the rhythm of the motion of the planets around the sun. These frequencies are not the frequencies of the jumps between orbits. These are the frequencies of the orbit themselves. They have their background in classical mechanics and the jump frequencies have their background in quantum mechanics. Bohr postulated the correspondence principle which stated that in the

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14 Hoffman, p. 84.

limiting cases of large masses and of orbits of large dimensions, quantum mechanics must pass over into classical mechanics. These two types of frequencies--jump and orbital--and thus classical and quantum mechanics can be correlated by using Bohr's correspondence principle. This relationship worked for orbits far from the nucleus where energy differences were small, it did not work very well for high energy orbit. This principle--relating classical and quantum mechanics in a rather arbitrary fashion--was called the correspondence principle.

Heisenberg arrived on the scene at this point. The motion of a particle around a nucleus at this time could be designated by its position "p" and its momentum "q". Fourier analysis says that the "p's" and "q's" can be analysed into constituent sine waves, but Heisenberg put the frequencies connected with the "p's" and "q's" in a square table or "matrix". (Heisenberg was concerned because the Fourier analysis yielded frequencies which did not correspond to jump frequencies shown by distances between energy levels on an energy level diagram obtained from spectral analysis.) Heisenberg felt a reconstruction was necessary because previous theories were inadequate. Hoffman likens Heisenberg's square table to a mileage chart.[15] He likens the Balmer frequency ladder to a road with several different towns on it. Both the frequency-between-levels

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[15] Hoffman, p. 92.

information and the mileage-between-towns information is most easily shown in a square table as shown following:

Name of Town	Baltimore	New York	Philadelphia	Trenton	Washington
Baltimore	0	198	105	137	41
New York	198	0	93	61	239
Philadelphia	105	93	0	32	146
Trenton	137	61	32	0	178
Washington	41	239	146	178	0

Fig 2-3 . Mileage Table . The same type of chart could be used to present frequency-between-levels information. (After Hoffman, Strange Story of the Quantum , p. 92.)

Heisenberg made his square tables to represent the frequencies "p" and "q". He decided that in his work he could only use definite information, such as the Balmer frequency ladder. This meant that what had once been a definite physical quantity-momentum-was now a square mathematical table. Position too was a square table.

A timely, remarkable part was played by mathematics in this new theory of Heisenberg's. Although the levels on the Balmer frequency ladder could be named first, second, third, the theory itself was required to generate mathematically the correct definite frequencies and intensities for each level. Mathematics made this generating possible as we shall see later. Heisenberg now wished to use older forms which multiplied the "p's" and the "q's" to give valuable information. He developed a way to multiply his square tables in which different results were produced depending on whether one multiplied "p" times "q" or "q" times "p". By doing this Heisenberg unwittingly rediscovered matrix calculus. Again mathematics had been developed before the phenomena the universe called for it. Could this be evidence of the basically mathematical character of the universe?

The importance of mathematical operations and forms which generate values for observable physical quantities is great in quantum mechanics. Perhaps I should first clear up the usage of the various terms related to this topic. Matrix mechanics, wave mechanics and quantum mechanics are all used in this field. We have seen that in 1924 Heisenberg discovered matrices as a mathematical tool for explaining atomic systems. Later Schrödinger published papers which derived Heisenberg's results from what seemed to be different methods. He solved an equation like the wave equation of classical mechanics and produced what was an extension of de Broglie's ideas of the wave nature of matter and the matter nature of waves. The complex of theories by Schrödinger and Heisenberg was called wave mechanics. A more general theory advanced by Dirac and smoothed out by von Neumann from which Schrödinger's and Heisenberg's work can be derived as a special case is called quantum mechanics. Quantum mechanics requires a mathematical tool which will generate values; and will thus be able to deal with what Margenau called the latent observables of the microscopic world. This mathematical tool is called an operator. If an operator (a mathematical symbol directing an operation) is given, there are certain functions which when operated on by the operator yield a constant multiple of their former selves. In the equation $Q\psi(x)=q\psi(x)$ "Q" is the operator and "q" is the constant.[16] Mathematics, thus, yields information about our universe. This indicates that certain things in nature can be dealt with mathematically, even if they cannot be conceived in physical terms.

Heisenberg as we have seen had trouble confining himself to austere mathematical functions. In his statement of the uncertainty principle the momentum and position of such things as a physical electron cannot be known at the same time. Those who employ the mathematical theory see in the probability associated with the uncertainty principle another manifestation of the mathematical in nature. Are not probabilities mathematical concepts? As far as we know now, the only way to describe microscopic phenomena is in terms of probabilities. Quantum theory would seem to make mandatory the acceptance of these following three ideas, and thus to demand a place in reality for the mathematical concepts of statistics and probability:

(1) There is simply no satisfactory way at all of picturing the fundamental atomic processes of nature in terms of space and time and causality.

(2) The result of an experiment on an individual atomic particle generally cannot be predicted. Only a list of various possible results may be known beforehand.

(3) Nevertheless, the statistical results of performing the same individual experiment over and over again an enormous number of times may be predicted with virtual certainty.[17]

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[16] Margenau, p. 333.

[17] Hoffman, p. 181

The probability waves are described by the mathematical theory as having what Reichenbach calls thing-character. Thus, the waves themselves are the ultimate facts in nature.[18]

The mathematical theory has been taken from its birth in Grecian times to its success in quantum physics, and has thereby been given an historical definition. The logical consequences of its basic premise that the ultimate entity of nature is form have been discussed and brought to light, and the sense that its meaning is still incomplete has been obtained from the historical definition.

Specific Concepts in Physics as Described by the Mathematical Theory

The mathematical theory presents the concepts used in physics in a characteristic manner. Although its concepts lack the discrete, definite quality of those of the physical theory, they perhaps make up in completeness what they lack in ease of handling. A typical example is the electron as described by the mathematical theory. This "model" of the electron is bound up in wave and probability considerations.

Evidence for an electron being a wave was given by L. deBroglie in 1924. He described the outcome of combining the theory of relativity with Plank's quantum idea. The energy of a system, according to Planck and Bohr, was related to the frequency by:

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Reichenbach, p. 22.

$$E=h\nu$$

In this equation "h" is Planck's constant. deBroglie then assigned a vibratory nature to an electron of frequency ν. This step is typical of the rational mathematical theory because "we do not ask how this can be visualized or how it can be mechanically maintained."[19] A moving observer will see the hypothetical vibration as a wave rather than as an up and down movement. The wave according to the theory of relativity moves with a velocity of "V" for the observer. "V" is equal to:

$$V=\frac{c^2}{v}$$

Here "v" is the observer's velocity and "c" is the speed of light. Now if the Einstein mass energy equation is employed we have:

$$E=mc^2$$

From the above equations:

$$h\nu=mc^2,\ c^2=vV \text{ and}$$

$$h\nu=mvV \text{ or } \frac{V}{\nu}=\frac{h}{mv}$$

and finally using λ as wave length we have, since $\lambda=\frac{V}{\nu}$,

$$\lambda=\frac{h}{mv}$$

this means that an electron of mass m has associated with it a wave length $\frac{h}{mv}$. Could an electron be a wave? If the

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19 Margenau, p. 318.

electron were a wave it could be diffracted and perhaps polarized.

In our previous discussion of physical theory we saw that electrons had been diffracted in an experiment by Davisson and Germer by a nickel crystal to give a diffraction pattern similar to the pattern produced by X-rays. From the pattern which was obtained the wave lengths of the electrons could be computed. These computations were in agreement with deBroglie's formula. Electrons were later diffracted by a German named Rupp. He used an optical diffraction grating. Later experiments showed the possibility of polarizing electrons.[20] Electrons, at this point, had all the normal attributes of a mathematical wave.

Electrons were given another essential mathematical interpretation by Schrödinger. They were given a meaning in terms of the part they played in Schrödinger's theory of the atom. He finally developed an electron that could be expressed in mathematical terms, and that did not "jump" from orbit to orbit to produce light whose wavelengths could be used in making up an energy level diagram of the atom. Schrödinger's electron was a mathematical function. How could it jump? Schrödinger explained the spectral lines as evidence of the beats in frequency, of what he calls the ψ (psi) essence. A fuller discussion is required to grasp the Schrödinger concept of the electron.

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[20] Ibid., p. 20.

When Schrödinger first presented his theory, he gave none of its logic nor did he explain how it grew in his mind. He simply "reminded his readers that a certain well-known mathematical process yields series of numbers which might be used as quantum numbers, abruptly wrote down the wave equation now know by his name and proceeded forthwith to extract from it a magnificent solution of the crucial hydrogen problem."[21] Let us try to see how Schrödinger arrived at his solution. Schrodinger wanted a good mathematical theory of the atom. He realized that he needed a mathematical tool which would generate the quantum numbers in a natural manner. The physical meaning was unimportant. We have seen in our discussion of operators that operators will generate values which are proportional to the functions upon which they operate. Schrödinger could use the mathematical tool, but he needed more insight into the problem. A consideration of the phenomenon of vibration is needed to comprehend Schrodinger's insight. Vibration in a system fixed at both ends takes place only in whole numbers of segments. Likewise, a steel ring may vibrate in only whole number units. An electron's orbit around the nucleus is a type of ring. The whole number units in which it vibrates are wave lengths, characteristic of the orbit (not to be confused with wavelengths produced by electron jumps from one orbit to another). If the deBroglie wave lengths

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21 Hoffman, p. 110.

of the waves accompanying an electron in a Bohr orbit is calculated, the wavelengths come out just what they should be if the orbit is made up of whole wave lengths. Schrödinger saw that the vibratory nature attributed to orbits of the Bohr atom indicates the use of a wave equation. Wave equations had been used to describe other vibratory phenomenon--strings, organ pipes and electro-magnetic waves. Schrödinger also knew that a wave equation if operated on properly would generate values which might be helpful in his theory of the atom.

The originality of Schrödinger's theory was that the wave equation was not applied to an ordinary vibratory item. It was applied to an "essence" filling space which was called the ψ essence. When Schrödinger applied his wave equation to the ψ essence, he did not immediately solve the hydrogen atom problem. The frequencies of the ψ essence were the frequencies of the rungs of the Balmer ladder, not the differences in the frequencies between rungs. These differences in frequencies were the only frequencies that appear in a spectrum and need to be accounted for by any responsible theory of the atom. The spectral lines indicate electron jumps. If the electrons did not jump how were they responsible for spectral lines? The old electrons were gone. Hoffman says "they had been swallowed up by the new ψ essence, a vibrant smear of electrons surrounding the nucleus."[22]

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[22] *Ibid.*, p. 116.

Schrödinger still had to explain the spectral lines which were differences in frequency. He did this by employing the concept of the beat. A beat in music shows up when two different frequencies alternately cancel and reinforce one another. Schrödinger's ψ essence vibrates with frequencies which are the rungs of the Balmer ladder. The various beat frequencies of the Balmer rung frequencies turned out to be the exact differences in frequency which were required by spectral analysis. His theory was a success and the electron was no longer a definite physical particle. When Schrödinger completed his theory the electron was smeared. The ψ essence has been interpreted as the density of the smear.

Schrödinger's ideas brought problems into the mathematical electron theory. Schrödinger introduced packets to give his electrons position, but the packets did not stay together. A second after an electron's position was stated it was lost again because one could not know the motion and position at the same time. For this reason Bohr saw Schrödinger's waves as probability waves. Its position was known less and less well as time went on after stating its position. Its position became rapidly spreading probability.

Schrödinger's time equation gives the state of an electron at any time if its value at one time is known. This equation involves an operation which generates values of the type we discussed. It is given as follows:

$$H\phi = ik\frac{\partial\phi}{\partial t}$$

where H is a differential operator, ϕ signifies the state of the equation and k equals a constant.[23]

The mathematical electron grew away from physical concreteness due to Schrödinger's work. In his theory of the atom the electrons became a vibrant smear surrounding the nucleus.[24] Schrödinger's electron can only be spoken of indefinitely if we insist on physical terms; for Schrödinger's electron is basically a mathematical entity described by his wave equation and his time equation.

Mathematical space-time has been previously discussed: however, since it reveals the characteristic way in which a mathematical theory presents a concept used in physics, we will discuss mathematical space-time in detail. Space-time as presented by Einstein's theory had a continuity and a chrono-geometrical character which made it basically a mathematical concept.

It is an outcome of the invariance of laws of nature that if an observer in any Galilean frame (frame where acceleration effects are uniform) measures the spatial distance covered by a body and squares it (to negate the effect of minus direction), then subtracts from this number the speed of light squared times the square of the duration

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23 Margenau, p. 352.

24 Hoffman, p. 116.

required for the body to move, one will obtain an answer of invariant magnitude. The preceding statement is clarified by a mathematical equation. The equation is as follows:

$$dx^2 + dy^2 + dz^2 - c^2dt^2 = ds^2$$

The symbol "ds^2" is invariant. The "dx, dy, dz" symbols represent the change in space coordinates between two events. The speed of light is represented by "c". "t" is the time required to go from one event to another. The elements of the equation are squared in order to obviate the ambiguity of signs. It does not matter what frame an observer occupies; in every case, if "ds^2" has a definite value when referred to one frame, it maintains the same value when referred to another frame.

The invariance of "ds" brings something absolute into a world where even space and time change with the observer. "This was the first inkling we had in Einstein's theory of the existence of a common absolute world underlying the relativity of physical time and space."[25] This absolute entity that Einstein discovered was the mathematical "ds". The "ds" can be described as the square of a distance in a four dimensional continuum (time being the fourth dimension). It was called the Einsteinian interval. The invariance of all measurements in this four dimensional continuum led investigators to believe that there was an absolute value to the continuum itself. The continuum was neither

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[25] d'Abro, p. 195.

space nor time but pertained to both, "since a distance between two of its points could be split up into space and time distances in various ways, just as a distance in ordinary space can be split up into length, breadth and height, also in various ways."[26] The continuum was called space-time.

What was the geometry of this entity brought into being by mathematical consideration? Because we could write the equation describing an Einsteinian interval in ordinary Euclidian terms, we are tempted to call the new space-time Euclidian; however, for reasons beyond the scope of this paper the minus sign preceding the "c^2" and "t^2" indicated that the continuum is not quite Euclidian. It was called a semi-Euclidian four dimensional continuum with three positive spatial dimensions and time as an imaginary dimension.

Since time had been brought into consideration as basic in placing an event, a point could not designate a spot in the four dimensional continuum. A point in space-time was called a "point event". A prolonged event such as an object occupying the same space in successive instants or several different spaces in successive instants will trace out a world-line in space-time. The entity called space-time brought into being by mathematical insight, which requires a chrono-geometry to give it an adequate description is easily discussed in mathematical terms.

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26 d'Abro, p. 195.

For this reason it has aided us in comprehending the characteristic manner in which the mathematical theory presents the concepts used in physics.

There is still another theory of nature which presents still another logical view of nature. This theory is the functional theory. Its presentation will complete the description of the three basic ways of trying to comprehend nature and will give fuller meaning to all three theories. After discussing the functional theory, we may, then, proceed to investigate the manner in which these theories are used in individual philosophies.

CHAPTER III

FUNCTIONAL THEORY

An Historical Definition of the Functional Theory

The functional theory of nature considers the "event" to be the basic entity in nature. This term must be defined as it is used in the functional theory. For the functional theory it does not mean simply a happening. The word "event" has been used in this paper to designate a happening; however in regard to the functional theory "event" must mean the prehension of nature. It is an entity which has an essential unity. The event is the basic thing perceived. After Whitehead has cleared space and time from the taint of simple location as we shall do in this section, he defines the event as follows:

> The term (prehension) was introduced to signify the essential unity of an event, namely, the event as one entity, and not as a mere assemblage of parts or of ingredients. It is necessary to understand that space-time is nothing else than a system of pulling together of assemblages into unities. But the word event just means one of these spatio-temporal unities.[1]

Whitehead continues to define the event by saying that it is the basic element in our world of cognizance and that

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[1] Alfred North Whitehead, Science and the Modern World (New York: The Macmillan Co., 1925), p. 74.

since there is in the world of our cognizance, memory of the past, immediacy of realization, and indication of things to come, the event has a past, a present, and a future. This theory states the laws of nature in terms of the event. The historical definition of the functional theory of nature will be somewhat less chronologically complete than the previous two definitions. The functional theory is not tied closely to physical experiment; therefore no single development in physics can radically change it. This theory develops only at infrequent historical intervals. It usually appears when a synthesis of mathematical theory and physical theory is needed. The functional theory usually develops chronologically after the physical theory and mathematical theory have appeared on the scene and have run into difficulties. A functional theory incorporates both matter and form, but considers these entities as secondary attributes of nature.

The functional theory first appeared in history when the Greeks began to study medicine and science seriously. As the mathematical theory superseded the physical theory, so the functional theory superseded the mathematical theory. Although we are primarily concerned with the theories of nature as they effect physics, the functional theory's history necessitates digressions into medicine and biology.

Hippocrates saw in the living organism a mechanical system. This led him to believe that defects in human organisms were caused by diseases which could be cured by putting the human machine back in order and not by diseases which were the inevitable results of a curse or of bad luck.

He, therefore, directed his disciples to look for causes of diseases and to look for a possible pattern in the progress of a disease. Hippocrates was impressed by the obvious organization of living things. The organization that exists in living organisms later became a pillar of the functional theory. Organization indicates that a being is not just a group of material particles, these particles are put together in a certain way, usually for a certain purpose.

At this point Aristotle proceeded to build the superstructure of the functional theory upon the foundations laid by Hippocrates. After twenty years in Plato's academy, Aristotle was imbued with mathematics and physics. Aristotle, however, had a longing to examine living things. When after his formal schooling, he returned to the observations of living organisms, he became fascinated by the ability of living things to generate. Aristotle soon became convinced that generation was fundamental in nature. This meant that the real changes its properties. As Northrop says, "The acceptance of the principle of becoming was inevitable; the principle of being, and with it the physical and mathematical theories of nature, had to go."[2]

Aristotle became impressed as had Hippocrates with the organization of living things. Living things seemed to exhibit a formal as well as a physical existence. But both form and matter cannot be basic causes. It is useless to

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[2] Northrop, p. 19.

introduce a formal cause unless a living organism exhibits a form which material causes cannot produce. If a formal cause is necessary it changes the direction of motion of physical objects and becomes the cause. If only an external force will change the motion of material particles, then physical causes are basics. Either matter creates form or form creates matter; they cannot each create the other. Aristotle noted this, and therefore decided that matter and form are secondary to "becoming". Both organization and generation are essential to the modern functional theory. Organization comes from the process of abstraction and generation comes from the fact that the real is a process. Form and matter could interact because they became passive attributes. Aristotle regarded nature as basically a process in which, "its two major attributes (form and matter) are synthesized."[3]

The functional theory of nature in this stage of development reveals one of its primary consequences. If the real changes its properties, future effects cannot be predicted upon the basis of a knowledge of the present. Final as well as past and present conditions must be known if one is to predict. This is the principle of teleology. Teleology is basically a way of explaining. "This type of explanation is that in which the 'Why?' question about a particular event or activity is answered by specifying a

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[3] Ibid., p. 20.

goal or end towards the attainment of which the event or activity is a means."[4]

Another outcome of Aristotle's work, which is a part of all functional theories, is that because nature is essentially a dynamic unity made up of inseparable attributes the analysis of physics or of other sciences always involves an element of oversimplification and falsification. It is impossible, therefore, to pass from observation to a more real world. The real world is in the observation. The observer must be satisfied with taking a particular view of nature. Man's only way of getting nearer to an understanding of the totality of nature is to concentrate on one aspect and to know this aspect in detail. By knowing one aspect of nature in detail an appreciation of the unity from which it comes may be experienced. This is known as the method of abstraction and is the fundamental device used in investigation of nature in the functional theory.

This theory differs from the mathematical theory in the importance attached to sensation. The mathematical theory says that the real may be suggested by but is not given in sensation. Functional theory holds that the categories of science are but abstractions from observed nature and that the world of sensation gives real knowledge.

After the decline of science which occured in the Middle Ages as a result of an overemphasis on the rational

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4 Braithwaite, pp. 322-323.

and the other worldly, the functional theory was brought again to prominence by Thomas Aquinas. He shifted the theology of the Catholic Church from Platonism to Aristotelianism. This shift was partly responsible for the rebirth of science because it emphasized that nature was important in itself. The mathematical theory had seen nature as a secondary source of knowledge about the universe. A functional theory, as we have seen, emphasizes the fact that observation of nature will give real knowledge. A functional theory reigned in Western thought from the thirteenth to the seventeenth century.

Galileo and Newton departed from the functional theory and went back to the physical theory which provided a more stable basic entity. It is difficult to carry out experiments and to formulate laws if the object of the experiment as part of reality is continually changing. One weakness of the functional theory as a working theory is that one who accepts this theory must always be aware of change--not just change of the variables that he wishes to change but change of every part of his experiment. The real is changing in the functional theory. One must assume that certain variables can be fixed before he can have faith in his experiment. This is one reason that many working scientists have historically shunned the functional theory. It is unsatisfying and unfruitful as a theory for the laboratory. This is probably one reason why Galileo and Newton accepted the physical theory. The physical theory allows one to fix variables, to carry out controlled experiments, and to formulate causal laws with assurance of getting nearer the real. Newton had a faith in the predicting power of laws that would have been impossible if he had accepted the functional theory. One may feel that he is being most truthful if he admits that the real changes; but this attitude thwarts man's order-imposing, law-making drive. Therefore he must act as though certain aspects of the real remain constant if his action and law-making is to have meaning.

There is a long historical span before the functional theory returns in full force to play a central part in physics. Of course, this theory was always in the minds of investigators, and it served as an aid throughout the centuries whenever men faced a dilemma because of the inadequacies of other theories. We, however, will examine the functional theory's progress in this century because this era has added new meaning to it. The mechanical theory rose and fell. Electromagnetic waves were postulated and served to explain many phenomena. The physical theory and the mathematical theory alternately seemed to be the correct theory of nature in the centuries between Galileo and Einstein.

Because of difficulties that are extensions of the general theory of relativity, Alfred North Whitehead, the noted twentieth century mathematician and philosopher, was led to a functional theory of nature. His work with the functional theory greatly added to its meaning. As we have discovered, the relativity theory in physical terms states that matter conditions metrics and gravitational potentials. If bits of matter determine the metrics around them, then measurement of long distances, through different metrics, would be impossible. Macroscopic unity becomes difficult to explain. Whitehead saw that measurements of great distances were, indeed, possible, for many measurements had been made of distance between our planet and other heavenly bodies, and he decided that the physical theory was not adequate. His work gave further meaning to the functional theory. He decided that the principle of becoming is fundamental in nature as did Aristotle. In the particular case of the relativity theory, he saw the need for a space-time relatedness which was not conditioned by matter.

Whitehead accepted the functional theory idea that nature is a vast extensive process. Abstraction was for Whitehead the method one must use to derive scientific concepts. In connection with a discussion on space and time Whitehead says:

> It is hardly more than a pardonable exaggeration to say that the determination of the meaning of nature reduces itself principally to the discussion of the character of time and the character of space . . . I shall endeavour to show that they are abstractions from more concrete elements of nature namely, from events.[5]

One can infer from this quotation that, with Whitehead's work, the functional theory had developed to a point where it could describe specific concepts in nature (space and time) in its own terms. The first abstraction that we must make

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[5] Alfred North Whitehead, The Concept of Nature (Cambridge: University Press, 1955), p. 33.

in our attempt to transform our immediately sensed knowledge of nature into specific, communicable concepts, according to Whitehead, is to assign different parts of "the passage of nature" to different sets by means of the relation of simultaneity. We continue to apply this process of abstraction until we have definite concepts that can be manipulated and communicated but that are far from the sensed reality.

We have observed that relative simultaneity as seen by Einstein depends on the relativity of time. Whitehead admits the relativity of simultaneity, and therefore the relativity of time. However, his relativity of time is not due to the slowing down or speeding up of rhythmical systems; it is due rather to the fact that nature is so complex that one cannot be sure that the parts of the "passage of nature" are always assigned in the same way and to the same time system. Relativity, for Whitehead, is due to the complexity of nature and not to a physical process.

Space under Whitehead's functional theory has meaning only in a given time system. Since time is relative and since space systems are connected with time systems, space is relative. Since the structure of space is constant and uniform for a given time system, metrical uniformity for long distances is plausible. Whitehead has, thus, developed a theory that provides theoretical support for the observed fact that long distance measurements can be made accurately. But as Northrop says, "The reader must decide whether a doctrine which places the source of relativity in an intrinsic ambiguity in nature's passage and which admits all the relativity which psychological immediacy entails can provide foundation for scientific findings."[6]

Whitehead developed the functional theory far more fully than this presentation shows, however, this discussion has served to place Whitehead in the history of the functional theory. His development of the functional theory is closely connected with his own philosophy, therefore we shall discuss Whitehead further when we discuss various individual philosophies.

Quantum mechanics and recent work with high energy particles have found a place for the functional theory, but it is a much debated position. The functional theory has, nevertheless, gained added significance from its contact with quantum theory. Heisenberg's principle of indeterminism brings the concept of potentiality into physics. This principle indicates that it is the real that is uncertain and changing and not just our knowledge of the real. The electron at a given instant is unlike the electron of one second later, however, the electron of a given instant generates the electron of one second later. Heisenberg points out that quantum mechanics and recent work with high energy particles do bring potentiality back into physics. The fact that this book is so recent indicates that Heisenberg, who brought forth his principle of indeterminism

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[6] Northrop, p. 117.

in the nineteen-twenties, has thought a great deal about this matter and has decided that the functional theory has a real place in recent physics.[7]

Heisenberg speaks about Aristotle's idea of "potentia" which we have called the principle of becoming. He interprets Aristotle thus: "All that we perceive in the world of phenomena around us is formed matter. Matter is not a reality but only a possibility a "potentia".[8] With this interpretation of Aristotle in mind Heisenberg says that in quantum theory all the classical concepts are correlated with statistical expectations when applied to an atom. He further states that only in rare cases may the expectations become the equivalent of certainty. The expectations involved are not objective, but there exists an objective possibility a "potentia" in the sense of the Aristotelian philosophy. Heisenberg makes an interesting point in favor of the validity of the functional theory and its "potentia" when applied to quantum mechanics by saying that the language actually used by physicists when speaking about atomic events produces in their minds notions similar to the idea of "potentia". The electron orbit is not a reality but a "potentia". The functional theory stresses becoming and the event as fundamental in nature. Heisenberg when speaking of quantum mechanics speaks of potentiality, one form of becoming,

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7 Werner Heisenberg, Physics and Philosophy (New York: Harper & Brothers, 1958), p. 4.

8 Ibid., p. 147.

as being fundamental. The functional theory because of the part it plays in quantum mechanics has a fuller meaning.

The use of the functional theory in work with high energy particles is illustrated by Heisenberg in Physics and Philosophy. He relates the manner in which basic forms of matter other than the electron, e.g. the proton and the neutron, can be created and destroyed by cosmic radiations and by accelerators.[9] These experiments show the mutability of matter. At high energies particles can be annihilated into energy or created from energy. Matter is potentially energy and energy is potentially matter. Heisenberg points out that this situation demonstrates Aristotle's idea of "potentia".[10] Matter is continually becoming energy and energy is becoming matter. The real universe is, therefore, changing.

Heisenberg contributed an important ontological point when he reinstated the concept of potentiality in physics. By doing this, he denies Einstein's idea that "God does not play dice." That is, he denies that nature is an omnicomplete unchanging object which is obscured only by the epistemological limit of the finite human mind. Heisenberg strongly indicates that nature itself is changing and must be described by probabilities.

The historical definition of the functional theory

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[9] Ibid., p. 159.

[10] Ibid., p. 160.

has lacked the chronological exactness that characterized the historical definitions of the physical and mathematical theory. This treatment has also contained more individual ideas than the other two treatments. It has, however, enabled us to see the functional theory in its most meaningful light. We have seen the functional theory as a theory that appears on the scene after a great stride in physics has taken place, and that explains the far-reaching meaning of the stride. This gives the truest statement of the functional theory.

Specific Concepts in Physics as Described by the Functional Theory

The functional theory of nature through its interpreter A. N. Whitehead admits the relativity of simultaneity but does not derive this concept in terms of physical entities as did Einstein. Einstein uses physical motion or propagation to define the simultaneity of spatially separated events; he defines simultaneity in physical terms.

Whitehead's functional theory defines simultaneity differently mainly because it states that "there is an immediately given fact of simultaneity not merely for spatially coexistent events but for the whole of 'discerned and discernible' nature."[11] Simultaneity is, thus, defined

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11 Northrop, p. 116.

in terms of the immediately given. As Whitehead says, "The unity of this general present fact is expressed by the concept of simultaneity. The general fact is the whole simultaneous occurence of nature which is now for sense--awareness."[12] This idea of simultaneity can be meaningful only if one accepts the functional theory idea that the basic concept in physics is the event. "Now" must have a definite meaning. "Now" would have to be the event that includes a snap-shot of all nature in an instant. It does, perhaps, seem difficult to understand a definite physical concept such as simultaneity in terms of an intuitively given "now", however this is a necessary consequence of the first premise of the functional theory.

In these circumstances relativity of simultaneity arise from the fact that the "passage of nature" is too ambiguous to insure that the intuitively given simultaneity for the whole of nature is the same for all observers. In Einstein's discussion of simultaneity we saw that relativity of simultaneity arose from physical circumstances and not from within the observer. Einstein's relative simultaneity in physical terms was based on the constant speed of light and the relative velocities of observers. The functional theory relativity is based on the incapability of man to perceive the whole of the complex "passage of nature". For the

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12 Whitehead, p. 53.

functional theory "simultaneity is an ultimate factor in nature, immediate for sense-awareness."[13]

This concise presentation of the characteristic functional theory description of a concept used in physics reveals the vast difference between interpretations of the same concept. There is no right or wrong definition. Both the physical theory and the functional theory develop their concepts of simultaneity in a logical manner and both admit the relativity of simultaneity. The difference lies in the fact that they start from a different point of view. Are matter and motion fundamental in nature or is the event fundamental? This question can be put into the backgound; however the development of a satisfying individual philosophy requires an answer to this question. It does make a difference in the conclusion as we have seen.

Another concept in physics which the functional theory describes in a characteristic manner is the electron. The functional theory would not be at all troubled by the wave-particle controversy. L. deBroglie's statement concerning the possibility of associating a wave with an electron is entirely compatible with the functional theory. This theory has a logical explanation: the wave-like character of a bit of matter--the electron. The functional theory sees the wave aspect and the particle aspect as two manifestations of the same entity. Partial, seemingly contradictory,

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[13] *Ibid.*, p. 56.

views of nature are a natural consequence of the functional theory's idea that the real is the whole of nature at an instant and that we can only gain fragments of insight. Since, according to the functional theory, one can never expect to see the whole of nature, one must be satisfied with a partial slightly falsified view. Aristotle's method of getting nearer to an understanding of nature by concentration on a particular part and knowing it in detail--that is his method of abstraction would apply to the electron. One cannot expect to view the whole electron in an instant. One must be satisfied with a partial view at a particular time. In one situation the electron will appear as a wave and in another it will appear as a particle.

The electron of the functional theory of nature is potentially a wave, or a particle, or energy. Since the real is changing, the electron of this instant which is making a spot on a zinc sulfide screen and acting like a particle may in another instant be diffracted and act like a wave. The idea of potentiality which Heisenberg has recently stressed has great bearing on the functional theory's concept of matter in general and electrons in particular. Except for their greater stability, electrons could, if the functional theory's view is correct, be created and destroyed by accelerators just as have the smaller less stable particles. This, of course, has not been done. One problem connected with the functional theory's electron is that the charge on an electron is, to the best of our knowledge, a constant. If this real electron is changing as time progresses, how does the functional theory explain the apparently constant charge. It seems that "constants" must be regarded in the same manner that objects were regarded by Whitehead. That is a "constant" is something that appears unchanged in different events. The real changes because everything around the "constant" changes. The entire picture changes even though the same detail appears in each successive picture. The entire electron changes and the "constant" is in a different context each time we see it. In this manner an evolving reality is compatible with the existence of a "constant", and the electron of the functional theory can logically exist as a changing entity with a "constant" feature.

The electron of the functional theory is potentially energy, and it is potentially in various position and momentum states. It is a changing entity.

PART II

INDIVIDUAL PHILOSOPHIES
OF
PHYSICS

CHAPTER IV

LIAISON

Why, after all, have we gone to such great lengths to describe the various ways of viewing nature? Are not these theories of nature merely tools which are used by those who wish to form a philosophy? The answer to these questions is that one must really understand the possible ways of looking at nature before he can appreciate how others have philosophized about nature or before he can philosophize for himself.

Philosophies are so tied to individual men that they can never be understood as a group. The number and the subjective nature of philosophies of physics make any synthesis of them a doomed effort. An approach to understanding philosophies of nature is to try to see objectively the ideas and evidence which every individual has at his disposal. This is the reason for the preceding detailed discussion of theories of nature. But no instructive or even interesting purpose is served in listing endless facts and definitions. Facts and definitions must be absorbed by individuals, colored with subjectivity, synthesized, humanized, and presented as a philosophy before they stimulate discussion and become a vital part of the individual intellect. This is the reason for the following presentations of individual philosophies of nature.

CHAPTER V

THE PHILOSOPHY OF HENRY MARGENAU

We shall begin our survey of individual philosophies by discussing certain aspects of the philosophies of our contemporary, Henry Margenau. Henry Margenau in The Nature of Physical Reality pays tribute to the physical theory of nature by stressing the importance of empirical evidence in our investigation into the workings of nature. He also recognizes the importance of rational relationship which the mathematical theory of nature stresses.

Margenau forms his philosophy of nature in the process of searching for a meaning of physical reality. He finds that historically "the real" has had certain rather vague meanings attached to it. He says, "An appraisal of the meaning of reality, as the word is commonly understood, recognizes three vague criteria: the permanent, the "thing-like", and the efficacious in human experience."[1] These indefinite words are not satisfying to the scientific mind; therefore, Margenau begins his search in earnest by investigating ways science has of arriving at reality. Science, however, seems to be able to designate what is

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[1] Margenau, p. 10.

real without giving a meaning of physical reality. Science functions in two ways. It collects data and it develops theoretical systems. There is a tendency for advanced science to form theories; thus Margenau feels that an examination of the epistemology of theoretical science will aid his search for a meaning of physical reality. In the course of the examination Margenau's philosophy of physics evolves.

The examination begins with these questions. "What is immediately given?" "Can we depend on our senses to report the real world?" "Are physical objects, which we sense, as basic as the physical theory would have us believe?" "Is there a certain validity in the information given us by our senses?" and "What meaning can be attached to the concept of primary and secondary qualities, which suggests that perhaps our senses make us give the real world false properties."

In the course of answering his questions Margenau discusses the meaning of the breakdown of classical mechanics and the value of the quantum theory for our interpretation of the world. He feels that classical physics did not correctly discuss the immediately given because it failed to include the observer. It separated the spectator from the spectacle. Quantum physics accepted a loss of definition by substituting probabilities for preceptions; but it brought the spectator back into the immediately given. Margenau feels that the immediately given must be sought within experience and is not contained in an abstract world beyond this world. In this area he draws not only from the physical theory, but also from the functional, which emphasizes the all inclusive event as being the basic entity in nature. Experience, in the form of immediate experience and sense data, is shown, by Margenau, to be the terminus for cognition.

However, Marganau continues, one would not reach a philosophical point of view if he merely collected sense data. The data must point to something more meaningful. Margenau notes that the epistemology of theoretical science includes a way to get from experience to concepts, which he calls the "rule of correspondence". The concepts which embody and correlate sense data are called "constructs". The constructs are rationalizations of experience and as such they show the place the mathematical theory plays in Margenau's philosophy. Recall that the mathematical theory stated that the real is rational. Experience, in becoming complete and integrated, moves from the sensory and spontaneous to the rational and reflective.

Rules of correspondence are difficult to describe. They are not traffic directions which tell one just how to get from one place to another and they are not necessary steps of logic. They are step-by-step processes which enable one to pass from sense data to constructs.

> The rules of correspondence, are not eternally grounded in the nature of things, nor are they immediately suggested by sensory experience; they are important parts of every theory of nature and receive their validity from the consistency, the internal neatness and success of the entire explanatory scheme."[2]

Margenau's system of sense data, rules of correspondence and

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[2] Margenau, p. 73.

constructs is illustrated by the following model which appears in his book:

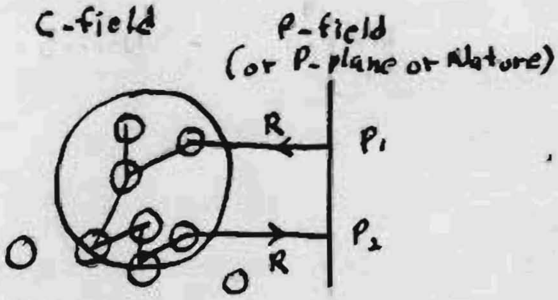

Fig 5-1. Illustration of connections between Margenau's constructs, sense-data and rules of correspondence. (After Margenau, The Nature of Physical Reality, p. 106)

One can see that the rules of correspondence lead from the plane of perception to the constructs and that they also serve as connecting links between constructs. There is haziness about the immediately given which helps make sense data incommunicable. In order to put knowledge in an understandable, communicable form, there must be a passage from data, on the pictured plane of perception to orderly knowledge via the rules of correspondence. The constructs which are formed, and into which our knowledge of nature fits, illustrate one major use of the mathematical theory. Margenau finds a crucial use for one of the basic entities of the mathematical theory-form. Form in Margenau's philosophy is required for the purpose of communication. Constructs, being rational, show another facet of their connection with the mathematical theory.

Constructs, Margenau says, are not completely determined by perception. "To be acceptable to science, as to common sense, constructs must satisfy two kinds of demands.

The first is a formal sort: it requires that every explanatory system possess a consistency and a logical fertility which sense data alone do not confer."[3] This first demand is a demand connected with the mathematical theory and it is concerned with form. Margenau in his investigation of the epistemology of theoretical science says that this demand makes certain "metaphysical requirements" for constructs. Some of these requirements are the requirement of logical fertility, the requirement of permanence and stability, the requirement of extensibility, that is applicability to many cases, and the requirement of multiple connections, that is the ability of the construct to be formally connected with other constructs and epistemologically connected with nature.

The second demand on constructs is empirical verifiability. This demand is evidence of a connection between Margenau's philosophy and the physical theory. Margenau does not allow rational forms to assume kinship with reality unless physical, empirical sense data support the validity of the rational concept. Empirical confirmation confers validity upon rational systems of thought. After one has gone from the plane of perception via the rules of correspondence to the area of the construct, he must be able to go back through the rules of correspondence to the plane of perception if his system is valid. This retracing of steps is empirical

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[3] Ibid., p. 99.

verification. But how can one tell if experimental and theoretical values agree? There is always uncertainty of measurement. Margenau solves the problem of how to find out when experimental verification exists by stating that agreement is reached if external and internal convergence of experimental data indicates an approach toward the theoretical value. Internal convergence exists if a great number of observations converge toward a mean. External convergence exists if as different instruments used to detect the same quantity are made more and more precise, all their readings point to the same value.

Margenau, while tracing the epistemological development of theoretical science, has developed a philosophy of physics. His tracing may have been as factual as possible but his conclusions are individual. He believes that both matter and form are essential in nature; however, he never clearly designates which plays a secondary role in nature, nor does he seem to support the functional theory which we have seen seems to be the only theory in which both matter and form can have the same status. Margenau develops a philosophy in which both form and matter play a definite part. He is not concerned with proving which of these is basic. He also believes that the spectator can never be spearated from the spectacle. He has been influenced by all three theories of nature. He never really chooses the entity which he considers basic and because of this his philosophy appeals to all readers, but never really gives a view if nature which can be reconciled with the impossibility of giving both form and matter the same status. Matter, form and the event cannot all be basic. We have seen in the discussion of the theories of nature that matter, form and event are mutually exclusive candidates for the basic entity in nature. The principle of parsimony dictates that there is no justification for introducing a formal cause in addition to the material cause, unless the universe exhibits an organization which the physical cause alone cannot produce. If an organization of this type existed then the formal cause would be the only and the primal cause. Margenau dismissed the basic differences between physics of continua and physics of discrete systems; that is the physics of a completely mathematical theory and the physics of a complete physical theory, by saying:

> Two alternatives with respect to the structure of matter, continuity and discreteness, have been recognized in the earliest stages of science and have at all times inspired controversies. . . . The question then is not whether matter is continuous but how theories succeed when they regard as a continuum the construct which they take to be their systems.[4]

This is a pragmatic view of reality and eliminates the necessity of giving theoretical evidence for making continuity, or discontinuity--form or matter--basic.

Margenau says that science both explains and describes the universe. It does this by isolating "systems", in definite "states" which contain "observables." Nature is described or explained by choosing a set of observables

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[4] *Ibid.*, p. 194.

which define the state of the system. The main differences in the physics of continua and the physics of discrete systems, Margenau says, is the difference in the systems in nature they use and the differences in the mathematics they employ. This idea is part of his philosophy of physics which attempts to describe the nature of physics by describing what physics does.

Margenau's philosophy of physics is concerned with the role of models in science. This concern leads him to a highly individual view on the particle and wave controversy. He states that there is no dualism. "Electrons and photons are neither particles nor waves."[5] Margenau says that we cannot build a model of electrons and photons in terms of the visual items we see such as cold, black, wave and particle. He believes that it is entirely consistent that an essentially invisible entity like the electron can not be described by a visual model.

Margenau comments on space-time, causality and probability, thermodynamics and statistical mechanics and each of these sections adds to his philosophy of physics; however, our purpose was to note in general terms his individual view of nature. Since this has been accomplished we shall, perhaps unjustly, forego a detailed description of the extensions of his general philosophy. We shall continue our investigation of individual philosophies by discussing

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[5] _Ibid._, p. 221.

the philosophy of Sir James Jeans. Jeans, of course, differs from Margenau in his use of the theories of nature.

CHAPTER VI

THE PHILOSOPHY OF SIR JAMES JEANS

Sir James Jeans builds his philosophy on one definite theory of nature. He has accepted the mathematical theory of nature in a restricted form and has used it as a foundation upon which to build his philosophy of physics. He answers the question, "What is physics?", by examining the nature of knowledge. His answer to the question, "What is physics?" reveals an interesting feature of philosophies of science. They can best be presented in an indirect method. Margenau reveals his own philosophy in the form of a supposedly objective investigation of the nature of physical knowledge. Jeans gives a supposedly objective definition of physics. Both these men are asking the same question in different ways and they both obtain different answers. We have seen that Margenau found physical knowledge to be inseparably physical, mathematical and functional. Jeans finds that physical knowledge is basically mathematical. I, myself, have approached the topic in an indirect manner. I pretend to begin by giving objective definitions of the different basic ways of looking at nature. I too reveal my philosophy of nature by choosing the method of approach as the reader will soon discover. The interesting point to note is that physicists approaching philosophy of physics try sincerely to begin objectively, but because philosophies in entirety are completely individual they reveal their points of view in the choice of approach and in the answers they give which are supposed to be the answers at which any logical man would arrive.[1]

Returning to Jeans and his definition of physics, we see that Jeans begins with perceptions as did Margenau. He says, however, that we perceive complex ideas from our five senses. Visual ideas, auditory ideas, tactile ideas and the like are mixed with ideas of aesthetic beauty and free trade. These ideas need to be correlated and categorized before they are useful for scientific manipulation. By noting number and quantity categories can be made. "We are left only with fundamental ideas such as number and quantity, and ideas which have entered our minds through the two senses sight and touch."[2] Jeans feels that visual ideas are more precise and "pure" than tactile ideas. He sees what we have called the mechanical view of nature as a manifestation of tactile ideas, which are, somehow on a lower level than visual ideas which are associated with geometries and the mathematical

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[1] The ghosts of those who passed before must be convulsed with laughter at my attempt at objectivity.

[2] Jeans, p. 11.

theory of nature.[3] Jeans, however, separates geometrical explanations of nature from mathematical explanations. He feels that geometries are basically pictures and that mathematics is concerned with relations. The formalism common to geometries and mathematical equations is not seen as sufficiently strong to hold the two forms together in one theory. Jeans concludes that due to the complexities of ideas received we can never hope to know the meaning of the ideas. We can only see the mathematical relations, therefore, for us the mathematical theory is the most valid theory of nature. Jeans says that physics tries to:

> . . . discover the pattern of events which controls the phenomena we observe. But we can never know what this pattern means or how it originates; and even if some superior intelligence were to tell us we should find the explanation unintelligible.[4]

As a continuation of the discussion of the relationship between philosophy and physics Jeans attempts to find out how we know--not just how we obtain scientific knowledge. Both he and Margenau feel that epistemology leads to knowledge of those things perceived. Margenau limited his investigation to a study of how we obtain scientific knowledge; however, both he and Jeans find that eventually both empirical and rational knowledge must be examined. In the course of a discussion of how people have known in the past, Jeans touches

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[3] We have seen this distinction in the historical definition of the mathematical theory. We saw that mathematical forms have historically been considered purer and finer than physical mechanical ideas.

[4] Jeans, p. 16.

upon the mathematical a priori knowledge claimed by the Greeks, Descartes, Kant and all expounders of the mathematical theory. He also touches upon the empiricists such as Locke, Hume and Newton who held that experience--usually with the here and now--was the sole source of knowledge. Jeans concludes that a priori knowledge has a certain unreliability as evidenced by the fact that predictions of physical events based on a priori knowledge often do not hold for macroscopic and microscopic worlds. He suggests that our "a priori" knowledge is knowledge based on experience in our own medium-sized world. Euclidian geometry, Jeans points out, was at one time considered, because of a priori knowledge, to be absolute--then came relativity and non-Euclidian geometry and the absolute aspect disappeared.

Jeans accepts a restricted form of the mathematical theory because he does not believe in the efficacy of a priori knowledge as did Plato and Descartes. His separation of geometries and mathematical relations should lead us to suspect that he would not use all formalism in the same manner. He stresses mathematical relation as being fundamental. He agrees with the empiricists that our sole source of knowledge is experience; but he does not consider the things we observe as basic. Although he stresses the value of experience as does the physical theory, he cannot be said to have accepted the physical theory because it states that things--matter and motion--are basic and Jeans states that relations between things are important. Jeans makes this clear in the following:

> We have seen that knowledge of the external world can come through observation and experiment. These tell us that the world is rational--its events follow one another according to definite laws, and so form a regular pattern. The primary aim of physics is to discover this pattern; we have seen that it can be described only in mathematical language.[5]

The whole history of physics is traced by Jeans. He begins with Plato, discusses the men we have discussed at various times, Newton, Einstein, Planck, Rutherford, Bohr, Heisenberg, deBroglie, Schrödinger and Dirac. From his handling of the history of physics one can discover that Jeans progressively loses hope of finding the basic entity in nature. He has to settle for a discussion of the basic entity in our <u>knowledge of nature</u>. Upon viewing the history of physics he becomes convinced that we can never know what is behind our knowledge. We can only guess. His guess is that mathematical relations are basic in nature itself, but his philosophy does not center around this notion. His philosophy centers around the idea that mathematical relations are basic in our knowledge of nature and that we can describe--not explain--the happenings of nature in mathematical terms. He brings in the functional theory idea that all our knowledge of nature is abstraction from the real whole under the topic of uncertainty. He states that the manner in which we divide up space-time is private and subjective.

That it is impossible to explain nature itself is, for

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[5] *Ibid.*, p. 82.

Jeans, not a dogmatic statement. It is a result of his ideas of perceptions. Any time we want to go beyond prediction of phenomena to understand them, we express a desire to go beyond mathematical symbols to a concrete meaning. This involves developing models and pictures, but any model or picture that is intelligible to us must be made up of ideas already in our minds. These ideas, as Jeans states early in the book, have entered our minds through the senses, and are thus not clear, precise and communicable. For this reason we cannot have exact knowledge of the basic in nature.

Perhaps a discussion of Jeans' views on causality will serve to illustrate certain points of his philosophy. He says that Newtonian physics presented a totally causal world. The position and velocity of a particle here and now determined where it had been and where it was going. Relativity theory also describes a causal world. The past did not create the future. Past, present and future were not sharply divided and were all part of an unalterable pattern. Quantum theory, at first seemed to upset causal theories, according to Jeans. Since the future path of a particle in quantum mechanics had to be described in probability terms the only way to maintain causality was to posit a sub-quantum system in which causality reigns. However as quantum theory grew wave mechanics and matrix mechanics evolved. "The mathematical equations of both forms of the new quantum theory, the wave mechanics and the quantum mechanics, are completely deterministic in form."[6] Jeans points out. These equations indicate that the world is merely unrolling, but the unrolling, for Jeans, is not the course of events but the course of our knowledge of events. "Causality disappears from the events themselves only to appear in our knowledge of events."[7] The characteristic philosophical conclusion that Jeans makes is that there is causality in our knowledge of events, due to the form of the equation we use to describe the happenings of nature, but it is a meaningless question to ask about the causality of the events themselves.

To further illustrate the implications of Jeans' philosophy of physics we shall examine his views on the wave-particle controversy. We have seen that there has been a good deal of evidence that radiations are wave-like. There has also been evidence that radiations are particle-like. We have also seen that electrons can be seen as a wave or as a particle. Which view of radiation and electrons is correct? Jeans answers that they are both correct. He says, "the wave-picture and the particle-picture do not show two different things, but two aspects of the same thing. They are simply partial pictures which are appropriate to different sets of circumstances."[8]

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[6] Ibid., p. 173.

[7] Ibid.

[8] Ibid., p. 133.

Jeans sees the two views as complementary rather than additive. We have seen that Jeans regards all mental pictures as imprecise aids to understanding nature. He says that the waves have no material or real existence apart from ourselves, and are not constituents of nature but of our efforts to understand nature. The mathematical formulae which these waves try to describe are unalterable and basic, according to Jeans, but our pictures, the waves, can change. The particles are also imprecise pictures to aid our comprehension, but of the two pictures Jeans, admittedly without conclusive evidence, favors the wave as being nearer reality. This again shows that Jeans is orientated toward the mathematical theory and tends to see reality in mathematical terms. After he reveals the manner in which the success of a particle-based picture of nature has in the past led people to the belief that nature was really like the successful pictures he says:

> Now that we find that we can best understand the course of events in terms of waves of knowledge, there is a certain presumption--although certainly no proof--that reality and knowledge are similar in their nature."[9]

Jeans does not exclude the importance of trying to understand and give meaning to physical terms, although the past progress in this field has discouraged him. He is not, however, a positivist; he does not believe that we must stop thinking when we have given relations to events. Jeans admits that the physicist cannot clothe his mathematical

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9 *Ibid.*, p. 203.

symbols with their true physical meaning; but he believes that physics and philosophy "may properly engage in joint discussion as to their possible meanings, and the most probable interpretation of the pattern of events."[10] We conclude our discussion of Jean's philosophy with this open-minded quotation because open-mindedness and a willingness to admit any new ideas is characteristic of Jeans' whole philosophy. The positivist would not agree with the quotation. They do not wish to go beyond descriptions of relations as we shall see in the following chapter.

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10 *Ibid.*, p. 82.

CHAPTER VII

THE PHILOSOPHY OF PHILIPP FRANK

A man who definitely fits into Jean's category of men who do not wish to go beyond descriptions of relationships observed in nature is Philipp Frank. In order to obtain insight into Philipp Frank's individual philosophy of natural science, one must realize that he is a product of a definite "school" of thought. This is the positivistic school. Frank calls his philosophy "logical empiricism"; however it is basically an extension of Comte's positivism as interpreted by Mach.[1]

Comte believed that all knowledge came from the senses. Not only color, sound and smell, but also the inter-relation of sense data was part of the knowledge given by the senses. He believed that eventually each science would formulate its laws in terms of relations. Descriptive formulae would replace explanations. The "whys" and "hows" would not be answered. Comte postulated the "Law of the States" which applied to all human thought; but which we shall present in terms of science. The first state according to Comte was the state in which humans made all explanations of phenomena

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1 An Austrian physicist of the latter nineteenth century.

in terms of theology. In this most primitive state man spoke of demons and gods causing natural events. In the second state phenomena were explained in terms of depersonalized forces and powers. This is the metaphysical state. The third state is the positivistic state in which phenomena are merely accurately described. No secondary, causal explanation is made.

Mach took the philosophy of Comte and revised and added to it. Mach outlined a program for reducing laws of science to perceptual elements. He added an interesting view of theories. He said, "The aim of natural science is to observe connections among phenomena. Theories, however, are like withered leaves which drop off after having enabled the organism of science to breath for a while."[2] Frank realized that he as a member of the "Vienna Circle" which included H. Hahn and Otto Neurath owes a great deal to his philosophical heritage. For this reason he devoted the first section of his book Between Philosophy and Physics to a history of positivism and its offsprings.

During this history and throughout the rest of the book, the positivistic idea that "a proposition has a meaning only if it states the means for its verification."[3] is a central theme. The idea of "meaningless concepts" is

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2 Philipp Frank, Between Philosophy and Physics (Cambridge, Mass: Harvard University Press, 1941), p. 30.

3 Ibid., p. 9.

a fresh and interesting idea which Frank proposes and which is an extension of the previous quote. A "meaningless concept" is a concept which cannot give the means for its verification.

Although Frank and positivism in general go too far in forbidding investigation beyond perception, they have done much to rid the philosophy of physics of metaphysical excesses. It is incongruous to forbid asking "why" and "how" of science; for, after all, science developed specifically to answer these questions; therefore positivism or logical empiricism ~~are~~ is basically weak. The existence of positivistic philosophy, however, requires that philosophers think long and critically before introducing a metaphysical explanation. The quality of scientific explanation is improved by the presence of positivism.

Frank shows how the positivism of Mach was transformed and brought out of its ivory tower by those who connected positivism to American pragmatism, and thus developed logical empiricism. All these "isms" are quite meaningless without explanation. What Frank wishes to show is that a presentation of the workings of nature as inter-relations between perceptions needs a concrete connection with the physical world to make it a dynamic concept. The concrete connection with the physical world of American pragmatism is incorporated by Frank. Frank's logical empiricism includes the attitude of American pragmatism toward "truth". "Truth" for Frank is not as an unattainable form as it was for Plato. Frank, as a true positivist, thinks that it is useless to speak of a truth that is forever unknowable. Frank feels very much as the American pragmatist William James felt. A description of Frank's interpretation of James' view follows:

> According to James, the truth of a system of principles, a physical theory, for instance, does not consist in its being a faithful copy of reality, but rather consists in that it allows us to change our experience according to wishes.[4]

Truth for Frank can have no meaning if it is held high above us lowly mortals. He cannot accept the ancient philosophy, which has in some forms filtered down through the centuries, that truth exists in a world above space and time and that the truth of human judgments are only good if they are faithful copies of the eternal truth. The concept of truth held by Frank is a concept which gives man's intellect a higher place than did the old philosophies, but it also makes man as a whole more lowly and materialistic. If the only worthwhile truth can be deduced by men from the information which is given them by their senses, then man can hope to know "truth". He formulates it, however, in terms of what will improve his physical situation and obtains "truth" only to better his own earthly physical surroundings. He cannot reach upward for an absolute truth. Some say this metaphysical communion with the absolute is nonsense; but at least it gets man out of a rut of self concern which can lead to self-centered pettiness.

The views on truth and reality discussed by Frank give much insight into the essense of his philosophy. Frank

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[4] Ibid., pp. 71-72.

would agree with Nietzsche and Whitehead in the idea that it is useless to divide the world up into "apparent" nature and "real" nature. Frank would say that what we sense is the only nature and that there is no reality apart from relations. Nietzsche expressed this view as follows:

> That things have a quality in themselves, quite apart from any interpretation and subjectivity; is an idle hypothesis: it would presuppose that to interpret and to be a subject are not essential, that a being detached from all relations is still a thing.[5]

Since in Frank's theory observations are the only path to truth or reality, it is reasonable that instruments and symbols which give bare relations are important to his theory. Instrument readings give relations and only relations are meaningful. Symbols represent the relations and serve the added function of dispensing with connoted words. The search of science according to Frank is a search for a unique symbol system. He says, "Every verification of a physical theory consists in the test of whether the symbols assigned by the theory are unique."[6] Frank illustrates this point by showing that one can express Planck's constant "h" in terms of quantities observed in black-body radiation or in terms of entities observed in Balmer series study. These are two different experiences denoting "h". If they agree, the system of symbols is unique and the theory "true".

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[5] *Ibid.*, p. 52.

[6] *Ibid.*, p. 81.

It should be noted that here there is no reference to things behind observations. Observations are the basis of truth. All questions concerning the nature of forces and matter and other physical concepts have become meaningless. "Only statements about concrete experiences are left."[7]

Another outcome of Frank's concern with symbols involves the difference between what are called causal laws and what are called statistical laws. He states that the task of physics is only to find symbols among which there exists rigorously valid relations and which (as we have seen) are assigned uniquely to our experience. These symbols can be related to experience in great or little detail. If they are assigned in great detail we speak of causal laws and if the correspondence is in less detail we have statistical laws. Frank believes that the statistical nature of the laws of quantum physics occur because symbols have been assigned broadly to experience.

Frank's view of the law of causality is characteristically positivist. The statement that, "The law of causality is only the establishment of a terminology" is made by Frank.[8] The reasoning behind this statement centers around the fact that we can express the same law in many different ways. All bodies, Frank states, can be provided with state variables which are qualitatively different if one wishes to fulfill

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[7] _Ibid._, p. 69.

[8] _Ibid._, p. 25.

the law of causality, or one can do away with qualitative differences and rely wholly on the physical theory by introducing matter and motion. In this case if the law of causality is to be fulfilled, one must, Frank says, introduce unconfirmable hidden motion in order to obtain the needed diversity. The law of causality can within Frank's philosophy be made to apply in any case if enough state variables are specified.

Frank's philosophy has strong ties with the mathematical theory. Jeans says that the study of physics has led some physicists to a positivistic conception of physics. In this positivistic concept of nature only relationships are valid, and relationships can best be expressed mathematically. Frank is one of the men to whom Jeans refers. The impossibility of obtaining a lasting world picture has led to Frank's statement that we must limit ourselves to describing the pattern of events in mathematical terms. The positivists, Frank included, believe that physicists may work in the field of physics using many different methods and techniques, but that the final harvest will be sheaves of mathematical formulae. The positivists believe that, "these will never describe nature itself but only our observations on nature. Our studies can never put us into contact with reality; we can never penetrate beyond the impressions that reality implants in our minds."[9] The preceding description applies to positivists and Frank in most areas has a positivistic

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[9] Jeans, p. 15.

outlook. He is a "logical empiricist"; however on this point he agrees with his positivistic teachers, and therefore he may be discussed as a positivist.

Frank does not believe that mathematical form is in any way the basic entity in nature. He does not believe that we know anything about the real world merely because we can describe events in the world. Mathematics, according to Frank, is merely a way of expressing our observation. Frank illustrates a key point in his philosophy by saying that if he can establish by observation the validity of the Euclidian axioms for a concrete physical triangle, then the sum of the angles in this triangle is equal to one hundred and eighty degrees. Frank states:

> In other words, the sum of the angles being one hundred and eighty degrees and the axioms being valid are only two expressions of the same thing . . . Once this has been made clear, the world, whatever it may be, will always obey the propositions of pure mathematics; the assertion that it obeys them says nothing about the real world. It says only what is self-evident, that all statements about the world can be replaced by equivalent statements.[10]

The important point made by Frank is that we develop a system such as Euclidian geometry in which one particular fact must be true. Then when we find this fact existing in nature, we turn about and say that this is evidence that the world is like the system we postulated. In the case of Euclidian geometry we conclude that the world is formal like the geometry if we find that the sum of the angles in a physical

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10 Frank, p. 122.

triangle is one hundred and eighty degrees. All we have done is to find what we put in the system. When we say we have discovered that the sum of the angles in a physical concrete triangle equals one hundred and eighty degrees, we have not proved that Euclidian geometry is valid; we have merely said that we are employing Euclidian geometry using different words.

Frank's individual philosophy could be called the philosophy of the uselessness of philosophy of physics. Frank's "logical empiricism" restricts statements in science to statements of relations between phenomena. According to this conception, "philosophical principles, which are not scientific in the above-mentioned sense, form a system of isolated propositions from which there are no logical bridges to the system of scientific propositions."[11] Because of this, a system of philosophy can never be confirmed or refuted by new theories in physics. It can, according to Frank, experience no improvement or destruction with the growth of physics because it is not connected to the moving forces of scientific discovery. Lastly Frank states that apparent improvement in philosophies of physics result from mistaking agreement in emotional coloring for agreement in logic.

Frank's philosophy has revealed some of the consequences of positivism. We shall view other consequences of positivism,

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11 Ibid., p. 192.

blended with influences from other philosophies, in our following discussion of the philosophy of P. W. Bridgeman.

CHAPTER VIII

THE PHILOSOPHY OF BRIDGMAN

P. W. Bridgman's philosophy is closely connected with positivism. The positivist's unwillingness to admit for discussion any statement which does not include the means of its verification, is evident in Bridgman's philosophy. He too is concerned with verification. Bridgman says, "In general, we mean by any concept nothing more than a set of operations: the concept is synonymous with the corresponding set of operations."[1] This illustration of the concept of length is used by Bridgman. He says that to find the length of an object we perform certain physical operations. He states that the concept of length is fixed when the operations by which one measures length are fixed. Not only physical concepts are defined by operations. If a concept is mental such as mathematical continuity, the operations that define it are mental.

Because of Bridgman's concern with operations his philosophy has been called "operationalism". This is, however, an incomplete name. We must examine the "why" of Bridgman's philosophy in order to see that "operationalism" only partly

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[1] P. W. Bridgman, The Logic of Modern Physics (New York: The Macmillan Company, 1927), p. 5.

describes it. Bridgman developes his philosophy against the background idea that scientists and philosophers of science must not develop ideas that will obscure progress for future generations. The reason Bridgman is so concerned with operations is that operational description is the only description we can use in conveying our knowledge to future generations without giving them subjective concepts which to them might well be meaningless and misleading. We only hinder progress, if we develop metaphysical explanations and pass them on to the next generation. If, for instance, we give all our descriptions of the happenings in nature in terms of an ether which will forever remain undetectable to us, then we are burdening our successors with the extra weight of a meaningless concept. They must waste their time getting rid of it or explaining phenomena in terms of it. Bridgman states, "We have seen that in setting up the general rules which are to guide us in describing and correlating nature, we have to take extreme care to allow no special hypotheses to creep in, as otherwise we might be restraining possible future experience."[2]

The concern which Bridgman shows for physical operations would indicate that he has been affected somewhat by the physical theory. He does believe that experience in the physical world is the physicist's only way to gain knowledge of

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2 Bridgman, p. 196.

relationships between phenomena in nature. He states that:

> The attitude of the physicist must therefore become one of pure empiricism. He recognizes not a priori principles which determine or limit the possibilities of new experience. . . . It may perhaps turn out eventually that as a matter of fact nature can be embraced by a formula, but we must so organize our thinking as not to demand it as a necessity.[3]

Bridgman believes that relationships are essential in a description of nature. This is evidenced by the fact that in Bridgman's philosophy every concept must be <u>related</u> to a mental or physical operation in order to have meaning. Relationships, as we have seen in our discussion of Frank's philosophy, are most easily expressed in mathematical terms. There is consequently, a place for the mathematical theory in Bridgman's philosophy. Bridgman, however, has absolutely no idea that nature is basically mathematical. He says, "the concepts of mathematics are inventions made by us in the attempt to describe nature."[4] It is difficult, Bridgman continues, to invent concepts which exactly correspond to what we know about nature. He feels that we need a mathematics in which the physical concepts have meaning. We need to "make our equations correspond more closely to the physical experience back of them."[5]

His philosophy, like the other philosophies we have

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[3] <u>Ibid.</u>, p. 3.

[4] <u>Ibid.</u>, p. 62.

[5] <u>Ibid.</u>, p. 63.

discussed, shows its individuality by the characteristic way it uses the physical, mathematical and functional theories. Bridgman's concern for keeping our description free from subjective constructs leads him to a concern for the operations we have mentioned. Two results of an operations-orientated philosophy emerge from a detailed discussion of the concept of length. The first result is that if we deal with phenomena outside the realm in which our original concepts were defined we may discover physical hindrances to performing the operations of the original definition. The original operations must, of course, give the same results as the old operation in the domain where both are feasible. But actually, in changing the operation we have changed the concept, and only convenience dictates that we use the same name for the concepts of the two realms.

The second result is that, "as we approach the experimentally attainable limit, concepts lose their individuality, fuse together, and become fewer in number."[6] We have fewer concepts on the horizons of nature, because we are capable of fewer operations in these areas. All our concepts must be given in terms of these few operations. Nature, thus, seems simpler on her horizons.

A third consequence of the operational character of Bridgman's concepts is that it is entirely possible to ask questions which are meaningless. In order for a question

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[6] _Ibid._, p. 24.

to have meaning in Bridgman's context, it must be possible to find operations by which an answer may be given to a question. Bridgman says in the way of an example that it is meaningless to ask whether a star is moving or not because we cannot perform operations to answer this question. He also states that in many cases operations by which questions can be answered cannot exist.

The idea that meaningless questions exist can save physicists from wasting time trying to puzzle out answers to impossible questions; however, there is a negative side to the idea of meaningless questions. The idea of meaningless questions, as well as the idea of declaring that investigations beyond relationships are pointless, are both, in a sense, stagnating ideas. If one accepts the idea of meaningless questions, he might be tempted to put difficult problems into the category of meaningless questions and thus be rid of them. It is important to leave every avenue of investigation open. Perhaps the meaningless questions of this generation will be a question of great importance to the next generation.

If a person is told often enough by positivists and operationalists, that only relationships between phenomena exist in nature, he may lose interest in the search. It is much more stimulating to work on a problem which has a solution and which might help to form a world view, than it is to work on problems whose answers will help place data in the correct column of a chart.

The model, Bridgman says, is "a useful and indeed unescapable tool of thought, in that it enables us to think about the unfamiliar in terms of the familiar."[7] Models, however, are dangerous because we may begin to think that they represent real experience instead of something inferred from experience. Mental models (constructs), Bridgman states, are made in order to help us deal with physical situations which we cannot experience through our senses.

After examining two specific mental models--stress in an elastic body and the electromagnetic field--Bridgman decides that there are two types of models: those to which no physical operations correspond other than those which enter the definition, and those which admit of other operations. This difference Bridgman stresses is evidence of a physical difference. We must guard against thinking that these models give actual pictures of nature and that they resemble each other. The models which admit of more than one operation are naturally the more useful and dependable models.

The importance of relationships can be brought forward in a context very different from Bridgman's or Frank's. It is intriguing to follow the diverging paths two minds will follow after starting at an identical point. We shall follow one of these paths by examining Whitehead's philosophy.

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[7] Ibid., p. 53.

CHAPTER IX

THE PHILOSOPHY OF WHITEHEAD

Unlike Margenau and Jeans, Whitehead does not find an examination of the "how" and "why" of scientific knowledge valuable in the development of his individual philosophy. He has a slightly positivistic attitude in that he believes the fruitful search for science to be a search for relationships among the things we actually perceive. The following comment appears in <u>The Concept of Nature</u>:

> the immediate thesis for discussion is that any metaphysical interpretation is an illegitimate importation into the philosophy of natural science (physics). By a metaphysical interpretation I mean any discussion of the how and of the why of thought and sense-awareness.[1]

In the light of the preceding comment it is understandable that Whitehead begins a discussion of the philosophy of natural science with definite statements of what is perceived in nature or as he says <u>termini of awareness</u> with "facts" of observation, not with speculation. The theory of nature upon which he bases his philosophy is the functional theory; consequently, he possesses the functional theory's idea that what is perceived

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1 Whitehead, p. 28.

is real and is changing. The only falsification and over-simplification occurs when persons must communicate and crystallize the "passage of nature" (that is the things perceived). It is, therefore, most reasonable that Whitehead immediately begins to discuss and define things related to sense awareness. For him this is a discussion of the real.

Whitehead firmly believes that dividing nature up into subject and object distorts nature. He is very much against the theories which propose bifurcation of nature. True to functional theory views, Whitehead believes that dividing nature into causal nature and apparent nature leads to a situation in which one is observing something entirely different from what he is describing. He believes that all our theories and ideas are attempts at determining the character of apparent nature. We wish to describe what we see, not a causal world which is forever shut from our vision. He states, "we may drop the term 'apparent', for there is but one nature namely the nature which is before us in perceptual knowledge."[2]

Nature for Whitehead is a huge extensive process which each individual views in part but not in whole. The viewer of nature in Whitehead's philosophy perceives the "passage of nature" or the event, and all other

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[2] Ibid., p. 40.

concepts are constructed from this entity. Although observation of the "passage of nature" gives the observer real knowledge, scientific concepts must be derived by a process of abstractions. Whitehead gives a vivid illustration of the process of abstraction when he is discussing how the scientific concept of a moment is derived from sense-perceived time. He illustrates thus:

> the (time) series may start with any arbitrarily assumed duration of any temporal extension, but in descending the series the temporal extension progressively contracts and the successive durations are packed one within the other like the nest of boxes of a Chinese toy.[3]

The only difference between the Chinese box and the time series is that in undoing the Chinese box one progresses toward a definite limit. Going down the time series one does not reach a smallest individual instant. One progresses toward an infinitely small section of time--an instant.

The least falsifying and first abstraction one must make if he is to devise scientific concepts is to divide the "passage of nature" or the events into different classes by means of the relation of simultaneity. According to Whitehead, as we have seen, simultaneity is immediately given. The light from a distant star and light from a lamp on one's desk are for Whitehead brought into existence simultaneously since they are sensed at the same time. Simultaneity, therefore, has no direct relation to physical constants such as the speed of light. In connection with

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[3] _Ibid._, p. 61.

this view of simultaneity Whitehead says that nature is inexplicable, a process which shows us durations that happen and pass.[4] Since our simultaneity exists as simultaneity in a system which is moving and changing in an inexplicable manner, we must depend on the immediately given to classify things according to simultaneity.

The relativity of time under this philosophy is derived from the fact that due to the complexity and ambiguity of nature not all persons will assign the same events to the same time categories. Whitehead speaks of several different time series existing in the universe. He is, therefore, able to incorporate the ideas of the relativity theory without injuring his own philosophical position. In each time system the numerous events exhibit certain characteristics. The events have a certain uniform constant relationship to each other which is called space, and they contain certain permanences which are called "sense objects".

Because there is no space apart from a specific time system Whitehead has a meaning for the relativity of space. Time is relative, and each time system contains a space. Space is, therefore, relative.

One of the philosophical advantages of having space depend upon relationships between events in a given time system rather than upon bits of matter is that the uniformity of space over a long distance can be made reasonable. If

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[4] Ibid., p. 54.

the physical theory were truly basic and if every bit of matter determined the metrics around it, long distance measurement would be extremely difficult to make. One would be measuring through several different metrics. If Whitehead's functional theory is accepted one realizes that "if the structure of space in a given time-system is constant and uniform and independent of the sense data and their controls which constitute molar objects the uniformity and constancy necessary for measuring exists, notwithstanding the changing relations of objects."[5]

The price that is paid for Whitehead's explanation of long distance measurement is that he must make definite physical concepts such as space, time and relativity depend on the vague concept of immediately given. Since relativity comes from ambiguities in nature, how can one tell when relativity exists and how much relativity exists. Time in the physical theory is a definite concept; but in Whitehead's philosophy it has become difficult to handle. It derives its meaning from immediately given simultaneity and a moment of it is an intangible limit.

Whitehead uses a more or less private language when discussing his philosophy. We have discovered the meaning of "passage of nature", "duration", "sense-awareness" and "apparent nature". Other words which are vital to his philosophy and which require a definition in Whitehead's

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[5] Northrop, p. 115.

terms are "congruence" and "recognition". Whitehead states that we become aware of objects because we recognize the same thing in several events. Objects are, in his philosophy, "elements of nature which do not pass". Since all of nature is a process and we are actually aware of passage we can recognize those things in nature which do not share in the passage of nature. These things which do not pass are objects.

Measurement, a basic concept in physics depends on congruence. Therefore the importance of Whitehead's theory of congruence to his philosophy of natural science can be seen. Whitehead believes that a theory of congruence is not a convention as Poincaré would have it. A theory of congruence, for Whitehead, derives its meaning from nature itself and depends on a theory of perpendicular, a theory of parallel, and a theory of motion. It is important to note that he believes that sense-awareness gives us a definite congruence and, consequently, a definite measuring system. This outlook is typical of functional theory. If we can sense what "the real" is in the functional theory, it is logical that we can sense "real" congruence. He says that his philosophy, "points out the factors in nature which issue in the preeminence of one congruence relation over the infinite herd of other such relations." One true congruence is possible because sense awareness gives us the ideas of perpendicular, parallel and motion upon which congruence depends. We recognize perpendicular in any event says Whitehead, but we do not generally recognize other geometrical relations.[6] We recognize parallel and motion in the same way. Measurement depends on congruence; congruence depends on recognition, and recognition depends on the immediately given association that an object perceived has been perceived before in just the same way. Again we see that Whitehead's philosophy makes a definite physical concept--measurement--depend on an indefinite sensation.

Whitehead's theory may be exasperatingly abstract, but then, it also has an appealing completeness about it. Whitehead points out that events are analyzed into the three factors, time, space and material and that often we mistakenly think of these three factors as independent. He denies that "these factors are posited for us in sense-awareness in concrete independence."[7] In this discussion the sometimes forgotten fact that what we perceive in nature is one unit factor is made. The over division which is prevalent in some philosophies of science is attributed to formal teaching and language which for convenience teaches us to express our thoughts in materialistic terms. This, Whitehead says, makes us tend to forget the true unity of observation. A refreshing concern for the reality of experience is a shining highlight of Whitehead's philosophy of physics.

Whitehead's entire philosophy cries out that the value

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[6] Whitehead, p. 126.

[7] Ibid., p. 75.

of experience has been lost in a maze of metaphysical concepts and mathematical formulas. The metaphysical search for a "how" and "why" in knowledge has destroyed the concept of reality by making it too vague and too far from experience. The mathematical formulas when taken as the basic entity in nature lose the concept of reality in a petrified forest of unmovable details. Reality, for Whitehead, is a process. We must realize, he says, that we oversimplify and falsify reality in order to discuss it and in order to communicate and manipulate our knowledge of the reality of nature. Since Whitehead believes that we can never see all of the process, it is not surprising that his expressions and even his words contain a vagueness which at times makes them unmanageable. The dilemma one experiences upon reading Whitehead is a sense that Whitehead has brought one closer to reality; but that on the way to insight one has lost the ability to communicate and handle his new-found knowledge.

CHAPTER X

VARIOUS VIEWS ON THE WAVE-PARTICLE CONTROVERSY

We have seen the manner in which individual philosophers differ, but we have compared differing views on specific concepts only indirectly. The present discussion is designed as a graphic description of the diversity of individual philosophies. This illustration takes the form of comparisons of the philosophical views of several men noted for their contributions to physics, upon a single subject. The opinions of Born, Landé, Reichenbach, Bohm, Margenau, and Frank on the wave-particle controversy will be contrasted and compared. As we have seen several other times, the wave-particle controversy concerns both matter and radiation. Is matter wave or particle or both? Is radiation wave or particle or both? There are many different answers as we shall see.

Max Born believes that both waves and particles have a type of reality. His view has, however, been called the unitary particle theory because he interprets the wave as a statistical distribution density of particles. The particle character of an electron Born says is evidenced by the fact that among the innumerable possible measurements certain types of measurment such as mass and charge have a permanent character. He says of these permanent features they "differ from those of ordinary perception, but are nevertheless in the same way indicators of things, objects, particles."[1] The waves for Born, have reality because the square of wave functions describes probability. Probabilities must be real since we make real physical predictions on the basis of probability; therefore, waves have a reality and are not empty forms. Born states that waves are needed to describe a physical situation because they describe the "state" of an atomic particle. Born summarizes his feelings toward the subject by saying:

> Even in restricted fields a description of the whole of a system in one picture is impossible; there are complementary images which do not apply simultaneously but are nevertheless not contradictory and exhaust the whole only together.[2]

Landé accepts the unitary particle aspect of Born's ideas; but he rejects the reality of waves. He believes that we have talked ourselves out of a basic paradox, by telling ourselves that electrons and radiation are both waves and particles. A unitary particle theory is presented by Landé. Landé, however, adds what he calls a "third movement". He says his aim is to "complete Born's Unfinished Symphony of description-plus-an interpretation by a Third Movement, viz., a realistic unitary particle explanation of probability interference and of other wave-like particle

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[1] Max Born, "Physics and Metaphysics", Scientific Monthly, 82 (May, 1956), p. 235.

[2] Ibid.

phenomena."[3] Landé thinks that what we mistake for waves are really manifestations of particles. The wave, for Landé, is essentially a statistical distribution of the density of a particle. Landé states that the statistical interpretation which Born gives to waves leads to the idea that waves describe the behavior of particles and are, therefore, secondary to particles and lack their own reality. He believes the epithet "real" should be withheld from waves, and thus disagrees with Born. Landé says that particles are real and waves are not real "for the same reason that sick persons are 'real', but wavelike statistical disease curves are 'constructs'--unless one wants to strain his language in order to save the face of duality."[4]

Landé agrees emphatically with Einstein's statement: "The concepts of physics refer to a real external world, i.e. to things (material bodies, fields, etc.) which claim real existence independent of perceiving subjects."[5] This is the reason he feels justified in talking about reality at all. He realizes that many philosophers of physics smile at the naiveté of using the word "real"; but he believes a discussion of the wave particle controversy must be carried on in terms of reality.

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[3] Alfred Landé, "Quantum Mechanics from Duality to Reality", American Scientist, 47 (Sept. 59), p. 345.

[4] Ibid., p. 344.

[5] Ibid., p. 342.

Reichenbach does not agree with either Landé or Born. He says that every experiment which seems to require the wave interpretation can also be described in particle terms and that any experiment that seems to require the particle interpretation can also be described in wave terms. This idea comes from Reichenbach's separation of the world of quantum physics into phenomena and interphenomena. The world of phenomena is, for him, made up of occurrences such as the coincidences between electrons which are connected with macroscopic data by a very short causal chain. The world of interphenomena is made up of occurrences such as the movement of electrons which happen between coincidences and which are connected with macroscopic data by a long causal chain.

The wave-particle controversy fits into Reichenbach's world of interphenomena. He says, "Given the world of phenomena, we can introduce the world of interphenomena in different ways; we then shall obtain a class of equivalent descriptions of interphenomena, each of which is equally true."[6] Arbitrariness of description is limited to the interphenomena world. The descriptions of the world of phenomena remain invariant. Since the subject matter of the wave-particle controversy is, according to Reichenbach, in the world of interphenomena, it is easy to see his reason for stating that both the wave and the particle interpretations

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6 Reichenbach, p. 23.

can be made for any given experiment concerning the electrons and radiations of the wave-particle controversy.

Bohm has yet another outlook on the problem. Bohm does not believe in the indeterminacy of the sub-quantum world; he believes that we just have not examined it closely enough. He has faith that upon further investigation a "sub-quantum mechanical level" will be found. He believes that each "fundamental" particle of physics is a body existing in a small region of space. Inseparably associated with the body is a wave which is assumed to be an oscillation in a new type of field. The field, for Bohm is still represented by the Schrödinger psi function, but for him it has a new meaning. The Schrodinger psi function is usually used as a symbol for the calculation of probabilities; however Bohm sees the field represented by the psi function as a real entity capable of exerting a force. Between the psi field and the body (electron, proton, etc.) there exists a new kind of quantum mechanical force which can be detected only for the atomic level. The field force tends to pull bodies into regions where the value of the field is largest. The random motion of the body resists this tendency.

Bohm, thus, sees the particle as basic; but also accepts a type of wave which exists in a field with a physical significance and which accompanies the particle. Bohm feels that his theory is compatible with all essential results of the quantum theory. His ideas could explain the famous example from quantum theory which shows that when electrons pass through two slits and fall upon a screen, they form an interference pattern as well as several discrete dots. Furthermore, the closing of one slit affects even the particles which pass through the other slit. Bohm's model yields this explanation. The interference pattern is produced by the waves associated with the electrons. Random motion and the passage of large numbers of bodies through the slit produce a statistical pattern of dots on the screen whose density is proportional to field intensity. "The quantum forces, in other words, account for the concentration; the random motion accounts for the irregularity of the array of particle images."[7] The effect produced by closing one slit is explained by the idea that closing one slit influences the quantum-force acting on particles as they go between the slit and the screen.

Henry Margenau's philosophy leads him to an opinion on the wave-particle controversy differing from all those previously stated. Margenau says simply, "Electrons and photons are neither particles _nor_ waves. They are no more one or the other than they are hot or cold, red or blue."[8] Because electrons and photons are not observed in the visible world, Margenau thinks that it is folly to give them visible properties by calling them waves and particles. We should, he feels, be satisfied with our positive knowledge of the

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[7] James Newman, Review of _Causality and Chance in Modern Physics_, by David Bohm, _Scientific American_, 198-199 (January, 1958), p. 112.

[8] Margenau, p. 321.

nature of an electron. We know its charge, its mass and its path at times. We should not try to translate our knowledge into terms like wave, particle, red and blue. It is stressed by Margenau that this attitude toward the wave-particles controversy is not an admission of our ignorance. He says, "We mean to claim it as a positive fact that an electron is neither particle nor wave, and we deny that we don't know what it is."[9] The fact that intrinsically invisible constructs do not display visible qualities, Margenau states is not a source of amazement. It is evidence of orderliness and consistency.

Frank calls the wave-particle discussion an "apparent" problem. His philosophy has no place for the "real" world, therefore it has no place for a problem that hinges on the reality of waves of particles. For Frank there are several different physical worlds because observations fit into several different systems and the only kind of knowledge Frank allows is observational knowledge. He says, "We could choose some physical world as being especially suitable, and designate it as the 'real world'."[10] Harm for science begins only if we forget that the real world is one of many possible physical worlds. In regard to waves and particles Frank is not concerned with the mental picture that people use to explain observations. He is perfectly

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[9] Ibid.

[10] Frank, p. 137.

content with uninterpreted data. The relations between results of one experiment and results of another experiment, and relations within one experiment as conditions are varied are the only factors that concern Frank. The fact that some persons interpret the relationships as evidence of waves and that others interpret them as evidence of particles does not alter the relationships, and thus does not concern Frank.

These men have all seen the wave-particle controversy in a different light. They have all been consistent with their philosophies. They have not been emotional or vague. These men are all respected in their field. Each of them has a valuable contribution to make to the discussion of waves and particles, and yet they do not agree. This, accompanied by the array of individual philosophies that have preceded this chapter, is convincing evidence for the assertion which was made in the introduction that a philosophy of science is essentially an individual idea. Such ideas are developed by inspecting the various theories of nature--accepting them or rejecting them--and building upon the accepted theories. The theories of nature always play some part in a philosophy of nature. Even persons such as Margenau and Jeans who begin the development of their philosophies of physics by investigating the nature of physical knowledge, make definite use of either the physical, functional or mathematical theory. Philosophies of physics are so individual that it is difficult to find a link which ties them together enough to enable a rational discussion of these philosophies. The link, though sometimes not a strong one, is that they all employ the theories of nature.

PART III

A GENERAL VIEW

CHAPTER XI

THE MOUNTAIN OF REALITY

We have wound our way through the words, the illustrations, the implications, and the facts that make up the three distinctly different ways of looking at nature. The physical theory, the mathematical theory, and the functional theory have thus been panoramically displayed for us. We have been presented with a glimpse of how other men have used these different views in developing their own philosophies, and we are left with no complete body of thought that could be called <u>the</u> philosophy of physics. Sharp agreement and dim correlation can be seen as the individual philosophies are compared, but only this striking truth appears: What is real for one man and for one age may be fantasy for another man and another age.

This, however, is not the sort of truth that is relevant for the dynamic creative work required of a physicist. Somewhere in the background of his work the physicist needs a concrete reality upon which to build. Even if a physicist's reality is the assertion that there is no "reality" and that only relationships are meaningful, he has a definite foundation upon which to build. He has a purpose for recording and tabulating vast numbers of readings from voltmeters, barometers and other instruments of the laboratory.

For those of us who find unbearable a universe without an absolute which is beyond the vagrancies of human thought and human emotion, there is a constant pattern which emerges from the histories of theories of nature and the studies of the individual philosophies. This pattern is a pattern that shows reality changing in a cyclic manner, for an individual viewer. We discover that reality changes but that the pattern remains constant. The pattern can be the absolute reality for which we search, but it is not the reality of now. We only discover the pattern as time goes by. We do not see the whole pattern at any one time and therefore we do not see absolute reality at any one time. We rely on belief to justify the existence of an absolute reality or a whole pattern.

Both individuals and mankind as a whole begin their search for knowledge of nature on a low level where reality is made up of hard concrete objects that one can touch, feel, and smell. This is the stage of the completely physical theory. The path of an individual man toward knowledge of nature is much the same as the path of mankind. After he has grasped the workings and interrelations of concrete objects, man wishes to connect and manipulate his knowledge. He employs mathematics to make his correlations easier and soon he finds himself attributing to nature the form and continuity of what had been only his expression of his knowledge of nature. This is the stage of the mathematical theory. Man soon sees that form alone cannot account for the dynamic nature around him. Mankind or man at this stage may revert to the physical theory believing it to be more compatible with the world of his senses. He may, however, try to synthesize form and matter, and thereby produce a theory in which becoming is essential.

This process by which man discovers nature is not entirely a step-by-step process. After a man or mankind has once been through the physical, mathematical, functional theory cycle, the three theories occupy his mind simultaneously. At certain times one becomes predominant and the others recede into the background. Each individual philosopher whose ideas we discussed was aware of all these views. However, at the time he presented the views that we read, each of these men was at a different place in his individual growth. This caused him to connect and to utilize the three basic views of nature in a different way. Looking at the history of physics we see the same sort of pattern at any given time. One particular theory may dominate; but even at the height of dominance of one theory some minds are working diligently on the logical and empirical development of the other two theories.

Each philosopher of physics and each period in history is situated at a different place on "the mountain of reality". This "mountain of reality" can be thought of as the pattern we have discussed. The mountain has three faces and a road that circles it while spiraling to its top. Each time a traveller up the mountain makes a full circle he has returned to a specific way of viewing nature. The traveller or travellers in search of knowledge of nature start out on the physical theory face of the mountain, proceed to the mathematical theory face and finally come to the functional theory face. They go through the same cycle again and again.

The history of science, thus, tells of mankind's progress up the "mountain of reality". We cyclically return to each of the three definite views of nature and each time we return we have all the benefits of a more all-encompassing view. From high up on the mountain the differences between the different views become hazy. This is why modern theories are not so easily and distinctly divided as were earlier theories. Although the "mountain of reality" does not change, reality for mankind changes as he progresses up and around the mountain.

The history of the development of an individual, in respect to the physical world around him, is a history of an individual's progress up his own replica of the "mountain of reality", and it is the history of his progress with the rest of mankind up the mountain. As a child, an individual is on the bottom level on the physical theory face. He is like the early investigators in the history of mankind. He sees the world as a mixture of hard concrete objects and soft objects. As a child an individual can think only in discrete terms, and his experience confirms the idea that the universe is basically made up of still and moving objects. At this level he develops, usually unconsciously, a completely physical theory of nature. As the individual grows, he finds that some objects can be easily connected. He also finds that it is much easier to express his knowledge of the world with the aid of a formal sentence or a mathematical equation. When he gradually, knowingly or not, begins to think of the world as being basically like the expressions that state his knowledge of the world, he has come to the mathematical theory face of the mountain. If he becomes dissatisfied with a world of static form and if he is particularly sensitive to the changing in nature, he will develop a functional theory and complete his first cycle.

Problems arise in the functional theory that seem to defy sophisticated analysis and man or the individual must return to the lowest level of reasoning in order to be able to handle the concept. This requires a return to the physical theory. The cycle, then, begins again.

The individual's progress up the "mountain of reality" differs from mankind's progress in that he has a very limited amount of time to make his journey, which means that he may only make a few circles on his own replica of the mountain. An individual is born at a definite time and place in mankind's history; his progress is, thus, limited not only by time but by the prejudices of the views prevailing during his lifetime.

By viewing the history of an individual's or of mankind's philosophical progress, we see that unchanging reality--the whole mountain--can never be viewed by mankind or by individual man until he reaches the top. Histories help us to look down the mountain and see what has gone before, but we as individuals or as mankind are on the mountain, and thus have a limited view of its entirety. We progress upwards and around and reality changes; but history indicates that we are seeing "something" from different perspectives as we travel. That "something" for the people who need an absolute is the unchanging reality--the mountain itself upon which we travel and of which (at a given time) we view only a part.

The "mountain of reality" is a needed context in which we can comprehend the change of something that all our experiments, our senses, and our rational thinking has told us is real and fixed. In the scientific spirit we must believe in the reality given us by the combined efforts of our senses and our minds; however to maintain sanity we must devise a context in which the seemingly unchangeable thing of this moment can change. In moments of metaphysical insight we can say that the "mountain of reality" is the absolute reality for which we search and that it exists. However, since most of our lives are spent on a low level of <u>sensibility</u> we must usually admit that we merely <u>believe</u> that there is an unchanging real nature. Only at cèrtain moments do we <u>know</u> that this unchanging nature (the mountain) exists.

Since every individual makes his progress up the mountain toward developing a philosophy of physics by himself, and since very few individuals are born at the same moment in history's progress, it is not surprising that there is unlimited diversity in philosophies of physics. This diversity is a necessity if every individual is to develop a philosophy which explains and describes his reality. The agreements in individual philosophies are reasonable since we are all viewing, from different perspectives, the same reality.

In this context one can understand that in order to develop a philosophy of physics, one must first study the various ways of viewing nature which history has shown us in order to see clearly where mankind is on the "mountain of reality." The study of histories of various theories will show that mankind's developing a theory is:

> Rather like climbing a mountain, gaining new and wider views, discovering unexpected connections between our starting point and its rich environment. But the point from which we started out still exists and can be seen, although it appears smaller and forms a tiny part of our broad view gained by the mastery of the obstacles on our adventurous way up.[1]

A second aid in developing a philosophy is to see how and why various men synthesized the theories of nature in different ways. We can thus vicariously, to a certain degree, put ourselves on different places on the "mountain of reality". This gives our reality a broader scope, and we thus come nearer to describing the mountain rather than our particular view of the mountain. Reality becomes less changing; however we are still, at a given time, tied to one place in the history of mankind and of ourselves.

One's philosophy will reflect his position no matter how well he understands the philosophies of others. This is understandable and necessary; for, as we saw in the

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[1] Einstein, p. 159.

introduction, a philosophy of physics is an individual attempt to understand. Each individual views the mountain or absolute reality from a different perspective. The perspective depends on the individual's intellectual growth as well as on the growth of mankind at the time the individual lives. Because everyone is viewing the same reality from different perspectives, there will be some correlations between individual philosophies; however the reality that one individual is trying to comprehend is a reality which is not exactly like any other reality; therefore his attempt to understand reality, his philosophy of physics, will be entirely individual.

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ABSTRACT

The development of a philosophy of physics is an individual task. One can be assisted in the task by an extensive study of the three basic theories of nature--physical, mathematical and functional. Assistance also comes from a study of the manner in which other men have synthesized the theories of nature and their own experiences into philosophies of physics.

A theory of nature can best be studied by historically defining the theory and by then examining specific concepts seen in the light of this theory. One finds that the physical theory of nature posits matter and motion as the basic entities in nature and describes phenomena in nature in terms of these basic entities. The physical theory is found to be the theory that is first developed whenever mankind or an individual man is faced with a seeming enigma in nature. It is the lowest level theory.

The mathematical theory of nature, one finds, is the theory of static form, and logical structure. This theory takes form to be the basic entity in nature, and it appears historically after man has gathered great amounts of information by using the physical theory, and after man has discovered a need for forms and categories into which he can put his knowledge in order to render it manageable.

A functional theory is the last in the cycle of theories employed by mankind or by the individual in his unceasing attempt to explain the universe around him. The functional theory, one sees, is an all encompassing theory. It incorporates both form and matter by making them secondary entities in a universe whose basic feature is change. If there is a basic entity in this most sophisticated (highest-level) theory of man, it is the event--a type of smallest division of the changing world. This theory, one finds, comes about from man's inability to be satisfied with static form as the mode of expressing a world of sensed change.

After a detailed investigation of the three basic theories of nature one has a perspective that is invaluable in his attempt to develop his own philosophy of physics. He must, however, humanize and perhpas even color the vast number of facts he has assimilated; for the individual who wishes to develop a philosophy of physics is a man and men seem to gain clearer insight when knowledge is presented to them in the form of the thought processes of a fellow man. For this reason the person who wishes to form his individual philosophy will embark on a study of the individual philosophies of other men. He will discover in each philosophy the universal and the provincial--the phrase that applies to all time and the phrase that applies to only a narrow period of time. He must sift the incoming information knowing that he too will produce irrelevancies and universals and hoping that he will produce more universals than irrelevancies.

Each man who ievelops his philosophy of physics is chained to the period, and the prejudices into which he was born, and each man through a study of theories of nature and of the philosophies of other men has an opportunity to undo some of his chains. He, however, is limited by time and by the fact that he is a human being. He will not develop <u>the</u> philosophy of physics for there is no one philosophy of physics. Each man lives a slightly different life and views a slightly different nature. Each man's philosophy will automatically explain phenomena others have viewed (because every viewer of nature sees some of the same things), but it <u>must</u> satisfactorily describe and explain the nature he views and allow for his future viewing for this is its purpose for existing.