of theories. The practical success of a theory, as observed in its prediction of experimental data, indicates that physics has reached an antecedent which is consistent with the effects.[22]

Traditional philosophy holds that operation is consequent on being and that as the operation is, so is the nature. Interpreted in their modern setting, these maxims hold the key to the philosophical interpretation of the pragmatic test as applied to scientific theory. All being is active, for all being possesses form and obeys finality. The activities of a being are measured by its own nature which is their source. Being is not static, inert, completely passive. It is informed, hence active; it is finalized, hence purposeful and dynamic. If the operations of a being are proportioned to its nature which is their ultimate material and formal cause, we can, by a study of a nature's activity, come to a knowledge of the nature itself. It was such a thought which led Aquinas to affirm that since we cannot know the essences of sensible realities as they are in themselves, we can know them in an indirect way by their effects.[23]

On the level of physics, the data predicted by a theory yield a knowledge of the nature of the hypothetical antecedent. It asserts its superiority over others which are unsuccessful in predicting the facts. We know it by its works. We accept it for its practical success. It is tested by empirical means. It has sense for physics only in so far as it has reference to the empirical. Scientific theories may be formally judged by coherence. Their test and sign of truth is pragmatic. Because a theory is shown to fit the facts by its function, it has in some way represented these antecedents. The laboratory data demand proportionate causes which we can know, empirically, only from the data themselves. An hypothesis, it must be said, has somehow entered into contact with the antecedents of observed data when it is a reliable forecaster of the data themselves. *Operari sequitur esse.* Only by an empirical test can an empirical science live up to its forename, empirical.

But if physical theory is based formally on the coherence doc-

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[22] "Nous ne prétendous en aucune façon que pour une telle science la réussite *utilitaire* se substitue à la vérité, ce serait là à notre avis une conception barbare. Comme toute science, elle n'existe que pour être vraie," Maritain, J., *Les Degrés du Savoir*, p. 122.

[23] *De Ente et Essentia*, C. 5.

trine of truth and is checked by the pragmatic test, it is not wholly out of correspondence with the real world. Since it is able to predict phenomena, it has somehow entered into contact with the real antecedents which determine the phenomena to be what they are. Its compatibility with the facts has been tested in practice. It corresponds to reality in its own way. When a theory is abandoned, the new theory, as was already noted, must include those elements which enabled the old one to account for the facts.

In the nineteenth century, it was fashionable to construct models to represent the mechanical structure of the world. "I never satisfy myself," Lord Kelvin said, "until I can make a mechanical model of a thing."[24] Today, however, physicists proclaim that we must abandon models, put our faith in mathematical equations alone. "If a picture exists," says Dirac, "so much the better; but whether a picture exists or not is a matter of only secondary importance. In the case of atomic phenomena no picture can be expected to exist in the usual sense of the word 'picture,' by which is meant a model functioning essentially on classical lines."[25] The mechanical explanation of matter has, it has often been said, been abandoned by contemporary physics. The theories of quantum mechanics and of relativity have come to replace them.

But the word *mechanical* is used in a very narrow sense by the contemporary physicist who now applies it only to classical physics which claimed, as Laplace affirmed, to give a precise prediction of the subsequent state of a system from a knowledge of its previous state.[26] Physics is still mechanistic, in the broad sense of the word. It seeks to interpret reality entirely in terms of its component parts. Whether we are successful in measuring the

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[24] Eddington wrote: "The man who could make gravitation out of cogwheels would have been a hero in the Victorian age," *The Nature of the Physical World*, p. 209.

[25] *The Principles of Quantum Mechanics,* Oxford, 1935, p. 10.

[26] *Mechanics,* as used by the physicist, has many English meanings. It can mean the study of machines as well as the study of masses in motion. In the latter sense, it is not synonymous with "physics" but is a branch of physics. *Mechanical* has also been used to describe the order of nature or, as the physicist puts it, causation—the relationship obtaining between two phenomena which enables us to predict one from our knowledge of the other.

realities or not does not modify our conception of the subject-matter as purely partitive. We may have classical, relativity, or quantum mechanics. We still have mechanism which, as Needham has shown, is a methodological necessity of empirical science.[27] "Indeed," according to Dantzig "the latest development in physics may be interpreted as the final triumph of the mechanistic tendency."[28] Physics, as we shall later see, atomizes matter. It is mechanistic by its very method. Whether we are able to represent the measured phenomena in a precise picture like the Rutherford atom-model is another question. The phenomena are still theoretically picturable.[29] The formal character of physics is mathematical. In so far as mathematics treats wholes as sums of component parts, physics is still mechanistic.[30]

But the mechanical nature of physics consists in more than mathematical equations. Models, images, and ideas are still formed and used by physicists. If, according to reliable psychology, there is no intellectual thought without concomitant images, the physicist cannot escape into a world of pure mathematical abstraction. Physics is a physical science. "It is necessary to know to what the assertions of a scientific theory refer, and a physical concept is therefore required which defines the subject-matter of the science."[31] Images provide a check for the development of our mathematics with a view to applying them to a physical situation. It is physical discernment which determines what mathematics should

[27] Cf. *supra*, p. 11 ff.

[28] *Aspects of Science*, p. 227.

[29] In this connection, Maritain has well pointed out that philosophy and contemporary physics both begin in the visible world and proceed to an unpicturable one. But the quantum world is still theoretically visible. It is only privately unpicturable because of our lack of experimental finesse. The noetic world of the philosopher is invisible in its very nature, i.e., negatively unpicturable, *op. cit.*, pp. 94-95.

[30] "Les équations se sont transformées, les grandeurs sont différentes, les méthodes ne peuvent pas être restées les mêmes; mais le thème général, sur lequel la théorie physique est batie, a encore aujourd'hui le même caractère fondamental qu'à l'époque de Newton. La structure d'équations, des grandeurs et des données expérimentales constitue encore aujourd'hui la base de toute théorie physique," Frank, P., *La Fin de la Physique Mécaniste*, Paris, 1936, p. 43.

[31] Whyte, L., *Critique of Physics*, New York, 1931, p. 123.

be applied and when and where. Physical-mathematical systems did not develop out of a vacuum. They are not applied to one.[32]

The precision of our models in their relation to the real world is another question. Einstein, who still believes in the eventual possibility of giving an exact model of reality with the further progress of physics, suggests that models be retained and modified according to the lacunae required by the Heisenberg principle.[33] If physics today is materially physical and formally mathematical, we must advert not only to the way we are studying the real world but also to the world we are studying. The neglect of physical can only result in a fiction-world leading to skepticism, bringing the death of science itself. Dantzig finds models in "tensors and matrices, manifolds and their curvature, differential forms and their invariants. The continual use of such terms and phrases has finished by converting them into so many new patterns and to the extent that they conjure up in the minds of the experts definite physical situations, these weird patterns fulfill their purpose as fully as did the classical mechanical models."[34]

Vaihinger, in his philosophy of *Als Ob*, suggests that models are pure fictions. The scientist proceeds *as if* they existed. He has no right to make them real. They are the subjective tools of the mind searching after truth. Sense perception alone is real.[35] Idealism has made a strong bid among the ranks of modern scientists who write either formal tracts or *obiter dicta* on the philosophical implications of their work. Impressed with the mathematical superstructure of their science and its apparent disagreement with common sense, they exaggerate the activity of man's mind, just as positivism exaggerates its passivity. They separate the familiar and scientific worlds.

Eddington and Jeans have carried the idealist position among physicists to an extreme form. For Eddington, the world can be built out of a "formless background" with "Hamiltonian differentiation of an invariant function of the 16 measures of struc-

[32] Benjamin, A. C., *The Logical Structure of Science*, p. 258.

[33] *On the Method of Theoretical Physics*, p. 19.

[34] *Op. cit.*, p. 231.

[35] *Die Philosophie des Als Ob*, Leipzig, 1920, p. 186.

ture."[36] The familiar table known by common sense is, it is said, in a different world from the scientific table composed of electrons scattered through relatively vast stretches of empty space. Reacting from the Hegelianism of his erstwhile colleague, MacTaggart, Eddington becomes so puzzled by the meaning of existence and of objectivity[37] that his philosophy is wholly colored with a skeptical idealism. Laws are imposed by the mind. "Our whole theory [relativity] has really been a discussion of the most general way in which permanent substance can be built up out of relations; and it is the mind which, by insisting on regarding only things that are permanent, has actually imposed these laws on an indifferent world."[38]

For Jeans, "the final truth about a phenomenon resides in the mathematical description of it."[39] Science does not describe the world. It treats of only man's sense perceptions.[40] The universe is a "mental concept."[41] It is pure thought of God, whom Jeans, echoing a Greek maxim, describes as a pure mathematician.[42] Mathematics is the only reality. "That is all you know and all you need to know."

Eddington and Jeans are extremists. They do not represent the views of sound-thinking scientists in their popular works. Much less do they represent genuine philosophy. Their treatment of ultimate realities may be boiled down to a universalizing of the scientific method.[43] Because their books are written in popular style, the authors have gained wide recognition.

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[36] *The Nature of the Physical World*, pp. 230-241.

[37] *New Pathways in Science*, New York, 1934, p. 291; *The Philosophy of Physical Science*, p. 69: "The purely objective world is the spiritual world; and the material world is subjective in the sense of selective subjectivism."

[38] *Space, Time, and Gravitation*, Cambridge, 1929, p. 197.

[39] *The Mysterious Universe*, p. 176.

[40] *The New Background of Science*, New York, 1933, p. 259.

[41] *The Mysterious Universe*, p. 167.

[42] *Ibid.*, p. 168, p. 165.

[43] Russell has pointed out the arbitrary character of the attempt by Eddington and Jeans to reconcile religion and science on the basis of the scientific method. "Eddington deduces religion from the fact that atoms do not obey the laws of mathematics. Jeans deduces it from the fact that they do," *The Scientific Outlook*, p. 108.

It is not the business of scientific method to pass upon the objectivity of the universe and its ultimate structure. Physics can only measure matter. It cannot subject it to the intellectual analysis and synthesis employed by philosophy. Both Eddington and Jeans believe that they have explained away substance. They conceive it to be the solid resistant stuff in the outer world known to the sense of touch. In reality they have misconceived the traditional doctrine of substance. Substance is not the stuff we feel and touch. It is a being able to exist in itself. It need not inhere in another reality. An intelligible principle, it can be studied only intellectually. It is inaccessible to the method of physics.

Eddington and Jeans, who leave no legitimate place for a philosophical approach to reality, are victims of their own failure to distinguish methods. The familiar table of Eddington is a real table. But scientific method can only deal with aspects of its reality. The physicist must accept the familiar table before he can apply the analytic technique of his science. Contrary to Eddington's belief,[44] the physicist must borrow his raw materials from the familiar world. He must likewise check data, eventually in terms of the familiar world.[45] Our concepts in science are all, in their ultimate origins, formed from every-day life.[46] As Planck has written,

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[44] *The Nature of the Physical World*, p. xiii.

[45] "For there is nothing peculiar about the physicist's manner of perception; the world which the ordinary man perceives is also the world which he perceives; the only difference is that he perceives it under carefully selected conditions, in order that he may examine it more closely. . . . They (objects perceived by the physicist) must, that is to say, in so far as they are directly apprehended in sensory experience, possess in common with the objects of the every-day world such qualities as shape, size, colour, and temperature. If they did not possess these qualities, it would not be possible for the physicist to have sensory experience of them," Joad, C. E. M., *Philosophical Aspects of Modern Science*, pp. 129-130.

[46] "I venture to suggest that it is as absurd to say that there is a scientific table as to say that there is a familiar electron or a familiar quantum or a familiar potential. Eddington insists upon the lack of familiar parallels in the latter cases; surely he is justified in doing so. What is puzzling in his view is that there are parallel tables. . . . But if the 'scientific table' is to be regarded as the produce of the 'raw material of the scientific world,' how can it be regarded as parallel to the familiar table?" Stebbing, L., *Philosophy and the Physicists*, London, 1937, p. 58.

the common sense world "is an indispensable aid to the groping imagination of the investigator, supplying him with ideas without which his work remains unfruitful. . . ."[47]

The capital distinction which Eddington fails to make is that between subject-matter, or material object, and the point of view which a given science takes, its formal object. "In other words," Joad remarks, "there must be something which is other than the description to correspond with the description which is given to it; and it is to this something that the description applies."[48] The same neglect of distinction can be noted in the philosophy of Jeans. His final doctrine is that mathematics is the ultimate structure of the real. This is a confusion of subject-matter and point of view. "To say that the external world obeys mathematical law and to say that it *is* mathematical law is to make two very different assertions."[49] One is reminded of the aphorism of Leibniz, "Toute philosophie est vraie en tant qu'elle affirme, et fausse en tant qu'elle nie." Mathematics is included in the formal object of physics. It does not follow from this that mathematics is the only kind of being nor that the empirical approach is the only method of knowledge. *Qui bene distinguit bene docet.*

To relate the world of science to the world of common sense, Whitehead has proposed a three-fold division of objects. Perceptual objects are the " 'things' which we see, touch, taste, and hear . . ." as tables, stones, chairs, and so on;[50] sense objects are secondary qualities like color and sound, the proper objects of the senses;[51] finally, scientific objects are those entities like atoms, electrons, and quanta which "are inferred by reason of their capacity to express these characters, namely they express how it is that events are conditioned. In other words, they express the causal characters of events."[52]

In his division, however, Whitehead does not make the distinction between "thing" and "object." Without this distinction, his

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[47] *The Universe in the Light of Modern Physics*, pp. 10-11.
[48] *Op. cit.*, p. 77.
[49] *Ibid.*, p. 76.
[50] *Principles of Natural Knowledge*, p. 83.
[51] *Ibid.*, p. 83.
[52] *Ibid.*, p. 95.

views slope toward idealism, or at least agnosticism. For this reason too, the division does not explain how the scientific world can rejoin the world of common sense. A more orthodox philosophy sees the reason for this juncture in two principles: a) the "thing" is common to perception, to sense, and to science; and b) each one of these has a different "object" which is a real aspect of the "thing" proportioned to the knowing instrument, whether it be common perception, sense cognition, or systematized empirical science.

As in the case of Eddington's scientific table, it must be affirmed that scientific objects are derived ultimately from the conceptions of common sense. They bear the birthmarks of their origin. They must have physical properties, for they are still physical beings. An electron or a quantum is not merely a scientific *object*. It is a thing, the empirical aspects of which are objects of scientific analysis and the ultimate constituents of which are the interest of philosophy. A table or a stone is also a scientific object in this sense. It is a thing that has empirical aspects, just as an electron or a molecule. Scientific objects seek after the causal constituents of perceptual objects, as Whitehead indicates. In the process of study, the scientist merely refines the notions of common sense. His concepts and his symbols do not bear upon a different world. They merely represent empirically and in refined and corrected form the same world of common sense.

In summary, Whitehead writes: "The 'causal components' of a physical object are the scientific objects which occupy parts of the situation of the physical object, and whose total assemblage is what constitutes the qualities which are the apparent character which is the physical object apparent in the situation."[53] In this passage, Whitehead commits his usual failure to distinguish "thing" and "object." Hence, there can be no aspects to physical reality except that studied by science. Secondly, he fails to recognize that scientific entities also have apparent characters; otherwise, they could not be studied in physical experiment. Thirdly, this identity of "thing" and "object" and the dichotomy of real and "apparent" characters do not leave room for the extra-subjective thing where the ideas of the scientist and the *aspects* of *reality* that he studies

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[53] *Ibid.*, p. 189.

may meet in the *tertium quid*, reality, which enables theory and the entities it describes to avoid a vicious circle and which makes knowledge objective. Hence, Whitehead's system of objects veers toward idealism.

The methodological agnosticism of Vaihinger is rejected by the success of physics in predicting phenomena through the analysis of its mechanical and mathematical constructs. The philosophies of Jeans and Eddington—and the spirit of idealism among physicists generally—results from a failure to distinguish the empirical method of physics and the abstractive, analytico-synthetic, intellectual method of philosophy and from their consequent failure to distinguish the various formal objects (or points of view) that may bear upon the same subject-matter. Whitehead's idealist tendency also results from this failure.

A realistic philosophy does not insist that every idea in the system of physics be a copy of an existing being. Maritain characterizes the domain of modern mathematical physics as a "pseudo-ontological world where being of reason abounds."[54] But the beings of reason here are not purely logical constructs. They are *entia rationis cum fundamento in re;* they are akin to Plato's myths, grounded in reality but metaphorical in their ultimate form.[55] Science thus becomes a type of speculative art.[56] Rousselot held that Aquinas would have so characterized modern physics.[57] Art in the strict sense is not a way of knowing. It is a way of making. But here there is no question of pure art. The system of physics is not designed, so say the forward-looking men in the field, to know the ontology of matter. It is only to predict the results of experiment. The mode of representing, as a result, may partake of the charac-

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[54] *Op. cit.*, p. 363.

[55] *Ibid.*, p. 310, pp. 318-319, pp. 273 ff. Naturally not every being in physics is of this type. Cf. also: Benjamin, A., "On the Formation of Constructs," *The Monist*, vol. 38, p. 40: "More precisely, a construct or fiction might be defined as any concept whose content is determined to a greater, rather than lesser, degree by the selective and creative activity of the mind, and whose value as an element of knowledge is to be measured not by the accuracy of its correspondence with reality, but in terms of its capacity to explain."

[56] Maritain, *op. cit.*, p. 319.

[57] Rousselot, P., *L'Intellectualisme de Saint Thomas*, Paris, 1924, p. 146.

ter of an artefact. But as far as it is representative, it is knowledge. Hence, Maritain speaks of a speculative art, an art for knowing.

Bergson claimed that the human mind distorted its object, that it did not attain the real.[58] He therefore seemed to make knowledge almost a complete artifact, virtually the work of the *homo faber*. Maritain's insistence on the real foundations of human knowledge in science as well as philosophy avoids the extreme view of Bergson and the idealists. It provides the foundation for a realistic appraisal of the noetic character of science.

Hoenen has proposed the view that physical theories, properly tested, express an analogical relation to reality and that if superfluous elements are eliminated by proper experiment and reasoning, the relation may become univocal.[59] It is difficult to see how this latter relation could be brought about, even on the condition imposed by Hoenen, since, in dealing with a *hypothetical* cause, we cannot determine whether we have eliminated superfluous elements.[60] Hoenen bases his arguments for at least an analogical relationship between theories and reality, on Cajetan's principle: *Quidquid assimilatur simili ut sic assimilatur etiam illi cui illud tale est simili.* Maritain has insisted that this view must be tempered by a proper definition of the type of analogy which obtains in scientific theories. It is not, Maritain holds, an analogical cognition in the strict metaphysical sense of analogy; it is a relationship of symbolism.[61] Though they may seem distant in their terminology, the difference between the two thinkers may be one of words and not of ideas. Theories are not mere fictions. They may not be in one-to-one correspondence with reality. But they have a physical counterpart in some form.

Cohen has summed up the case against those who regard scientific theory as a mere mental figment: "But this fails to explain

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[58] *L'Evolution Créatrice*, p. 131.

[59] "De valore theoriarum physicarum," in *Acti Primi Congressus Thomistici Internationalis*, Rome, 1925, pp. 61-74; pp. 269-275; "Inquisitiones criticae in theoriam atomicam physico-chimicam ejusque valorem pro philosophia naturali," in *Gregorianum*, 1927, pp. 228-242 and pp. 417-442.

[60] Rousselot, *op. cit.*, p. 104, argues forcefully that all human knowledge is analogical, in the intellectual order.

[61] *Op. cit.*, pp. 85 ff.

why phenomena seem to occur as if the law of gravitation with its inverse squares were true, or why the properties of circular functions have proved most potent instruments for the discovery of important facts in almost all branches of physics. Doubtless equations are not vibrating strings; but is it not straining the dualistic dogma to assert that they have nothing to do with each other? Do not let us be misled by the term 'expedient' or 'invention.' A map or a chart is an expedient or invention. Yet if it fairly represents its objects, is it not because certain relations between its part are precisely those between corresponding parts of the objects represented?"[62]

Concepts of science actually work. Even technical symbols like a so-called psi function of wave mechanics or the gravitational components in the theory of general relativity have passed the test of experiment by which scientific theories must stand or fall. Though scientists may not be interested in the exact objective significance of their hypotheses, it is only by a mental blind-fold that we can completely sever the world of theory from the world of things.

Perhaps this whole problem could be avoided if it were asked in different terms. Our problem is not to demonstrate that scientific concepts bring the mind into conformity with the real world but to search out the noetic value of this scientific knowledge. Inductive judgments, as van Benthem states, are a fact.[63] Similar recognition must be accorded to the relation of theory and experiment. Given the space and time coordinates of a particle obedient to the law of falling bodies, we can predict its velocity at a given future moment. Wave-functions enable the physicist to predict with a high degree of probability phenomena which are verifiable in laboratory tests. Relativity predicted the deflection of light in a solar eclipse and accounted for the deviations in the perihelion of Mercury. We need not ask whether certain relations hold once they have been shown to exist by adequate experimental evidence. The problem of conformity is solved. The problem then becomes:

[62] *Op. cit.*, p. 227; cf. also by the same author, "The Logic of Fictions," *Journal of Philosophy*, 1923, p. 447.

[63] *Essai sur l'Induction, Son Domaine, Son Fondement*, Zwolle, Holland, 1923, pp. 2-4.

what degree of conformity does our mind have with the objective world? Even though the answer may be in certain cases that we have only reached a being of the reason, founded in reality, the conformity is still there. The work of the scientist is focussed on the correction and improvement of his theories to bring about their more thorough correspondence with reality.

No one has ever seen an electron, nor an atom either, for that matter. Yet we can arrive at a knowledge of correspondent realities, even though this knowledge may be moulded into the form of a mental construct. Though Whitehead's vivid language may overstate the thought, it is true that if "atoms are merely conceptual, yet they are an interesting and picturesque way of saying something else which is true of nature."[64] Imagination cannot picture the non-Euclidian spaces of the general theory of relativity. Yet it is possible to interpret these spaces by analogy to the so-called Euclidian space of sense intuition and thus to gain some knowledge of their nature. If physical concepts cannot claim at least an ultimate contact with the real world, then physics is not a science of the real. Theories successfully predict real phenomena. Only on the premise that they reach objective causes and reasons somewhere in nature can we find a sufficient reason for the successful prediction.

The coherence theory of truth, which has been suggested as a necessity of the method of hypothesis, as far as it hypothesis, does not rule out the conformity doctrine altogether. Scientific theories must adopt the coherence doctrine as a *formal* standard of truth. Pragmatism is a *sign* of truth. Yet in a *material* sense, there is a correspondence with the real world.[65] Theories cannot reach the world of existence through content. But they reach it in an indirect way through successful prediction in the existent world. By the very nature of hypotheses, we are forced to posit a cause which is consistent with the effects rather than one which is, and *is known to be,* their real ontological determinant. For even if it were the true cause and would never need subsequent correction, how could

[64] *Concept of Nature*, p. 45.

[65] How these statements can be reconciled will be discussed in the following chapter, dealing with scientific method from the point of view of strict logic.

we be certain of this relation? Hypotheses are not facts. If so, they are no longer hypotheses. They must be judged by different standards. But all theories, even as theories, when they are congruous with the effects as shown by proper experimental evidence must in some measure correspond to the real. The new theories must embody in their make-up the representational scheme which made the old theory, provided it had adequate empirical check, a successful instrument in accounting for facts. Otherwise, we should not be able to explain the success of the old theory, as Bohr has done with his correspondence principle and as Einstein has done in validating Newtonian mechanics for ordinary space and low velocities.

It was Francis Bacon who first spoke of crucial experiments to decide between two rival answers to a problem in nature.[66] Today, the *instantia crucis* is still regarded as being the reliable test between two competing theories. The prediction by a theory of facts which are not likely on any other assumption constitutes the surest guarantee of its validity. But in crucial experiments, how do we know that we have a real dilemma? How do we know that there are no other possible alternatives? " 'Crucial experiments,' we must conclude," according to Cohen and Nagel, "are crucial against a hypothesis only if there is a relatively stable set of assumptions which we do not wish to abandon. But no guarantee can be given, for reasons we have stated, that some portion of such assumptions will never be surrendered."[67] Since we cannot be certain that we have ruled out all *real* alternatives in a crucial experiment, our experiment can reach no further conclusion than one "which shows that the effects deduced are congruous with an already posed principle." This is additional evidence that whatever the degree of *material* correspondence with the real world, theories in physics, from a *formal* point of view, must be judged in the light of the coherence theory of truth.[68]

[66] *Op. cit.*, vol. 4, pp. 180 ff.

[67] *Op. cit.*, p. 221.

[68] In experiments, especially in cases of the experimentum crucis, questions are posed in the light of the theories to be tested. In this sense, "Every measurement first acquires its meaning for physical science through the significance which a theory gives it," Planck, M., *Where Is Science Going?*

In the foregoing discussion of scientific theory in its relation to truth, these three principles have been proposed: a) that theories are to be judged formally in the light of the coherence doctrine of truth; b) that the test of truth, which must by its very empirical character be a practical test, is pragmatic; c) that theories, because of their practical success, are in a material sense in correspondence with reality.

So long as the physicist employs the method of hypothesis—and employ it he must—he will not reach existent causes but only hypothetical ones. He will discover only "content." In his deductions, *existent* essence, the true middle term of demonstration will always be sought but will always prove elusive. According to the coherence doctrine of truth and according to physics, existence is sought through content. Traditional metaphysics covers both aspects when it refers to being as that which is. Here it is apparent why theories in physics are independent of the philosophy of nature; they cannot be subsumed under its ontological explanations of the real. Theories, as theories, in physics and a genuinely philosophical philosophy of nature can never meet. They do not contradict each other, complement each other, or coincide with each other. Theories emphasize content. Philosophy emphasizes being, the existent. So it is that the physicist is a perennial seeker. In Bradley's words, he takes the road of infinite regress, guaranteeing among other things the unlimited progress of his science. The bridge between content and existence just does not come within the purview of physics. So we have, in physics, that bridgeless gap between suppositions and true causes.[69] All the king's horses and all the king's men cannot span it.

p. 92. In this sense, "No universal judgment of science, then, expresses in and by itself a determinate meaning. For every such judgment is really the abbreviated expression of a meaning which would require a whole system of knowledge for its adequate expression. It is this larger meaning, which, so to say, animates the single judgments and gives them determinate significance," Joachim, H., *op. cit.*, p. 96.

[69] "Truth is the predication of such content as, when predicated, is harmonious, and removes inconsistency and with it unrest. And because the given reality is never consistent, thought is compelled to take the road of indefinite expansion," Bradley, F., *Appearance and Reality*, p. 165. Pragmatism, in its general sense, is equipped to serve the scientist in his search

It may now be asked whether theories are constructed to explain phenomena or laws, or if they merely describe the facts and generalizations of physics. The positivists tend to emphasize the descriptive character of science. For Comte, as it was already noted, "Every hypothesis, to be capable of being judged, ought to bear exclusively on the laws of phenomena and never on their mode of production."[70] This view in one form or another is a common doctrine of all the positivists. They rule out explanation from the domain of the sciences. They set up pure description as the end of knowledge. Description means, in the words of Bridgman, "to analyze nature into correlations, without, however, any assumptions whatever as to the character of these correlations."[71] Explanation on the other hand means interpretation in terms of causes.[72] A distinction is suggested between the two ideas on the basis that explanation seeks only after the *why* and description after the how.[73] But the questions are not fundamentally different. Description in its attempt at correlation must transcend the immediate data of sense knowledge as it becomes more and more complex. Eventually, it reaches causal determinants which are in

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for a self-consistent, all inclusive system. Thinking starts, according to Dewey, "from doubt or uncertainty. It marks an inquiring, hunting, searching attitude, instead of one of mastery and possession. Through its critical process, true knowledge is revived and extended, and our convictions as to the state of things reorganized," *Democracy and Education*, New York, 1923, p. 345.

That gap between content and existence is spanned by human intelligence and can never be traversed by discursive reason. It is what we shall later come to see as one of those immediacies which lie outside of physics and which is affirmed by man's mind, reflecting on experience in a judgment. Inseparable in reality but distinguished by man's mind, content and existence are reunited in judgment, reunited in the unity of being as seen by the reflective unity of man's spirit; it is this unity which renders both unnecessary and illogical the indefinite expansion required by scientific method (considered as a philosophy); by the coherence theory of truth; and by the pragmatism of James and of Dewey.

[70] *Op. cit.*, vol. 2, p. 318.

[71] *The Logic of Modern Physics*, p. 37.

[72] Meyerson, E., *op. cit.*, p. 65.

[73] Benjamin, A., *An Introduction to the Philosophy of Science*, p. 10.

the world of explanation.[74] Meyerson has effectively stated the case against positivism by showing that science is a study of the real and that it is explanatory by its nature as a science.[75] "Explanation," he writes, "consists in showing that given the ensemble of antecedents, that which follows can be inferred by deduction, being only the logical consequence."[76] This is precisely what the modern physicist attempts to do. If physics were purely inductive, positivism could argue more convincingly. But induction is only a state in scientific method as it is practiced. When deduction begins and one fact is shown to follow logically from another, we have projected, in at least a qualified sense, to explain consequents in terms of antecedents, not merely to describe the data.[77]

Theories tend to explain laws. In some way they tend to pro-
vide the causal background from which laws may be deduced.[78]
The manner of explanation depends on the aspect of theory em-
phasized in the reasoning process. If it is a so-called mechanical
theory, laws will be deduced by direct reference to the entities that
form the causal determinants of the observed results. It is a well-
known fact that Dalton's theory of the atomic constitution of mat-
ter was suggested by the laws of definite and multiple proportions.
These laws can be deduced from the atomic theory.[79] On the other
hand, the so-called mathematical theories, though they originate
in physical pre-suppositions and refer to the physical realities of
matter and energy which give meaning to their symbols, explain

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[74] *Ibid.*, p. 10, p. 197.

[75] *Op. cit.*, pp. 45-61.

[76] *Ibid.*, p. 67.

[77] "The mere sensory reception of any phenomenon does not constitute
science; science is the causal arrangement of the phenomena, and the recog-
nition is but the first step towards its achievement," Gotch, F., "On Some
Aspects of Scientific Method," in *Lectures on the Method of Science*, p. 28.

[78] Campbell, N. R., *Physics: the Elements*, pp. 140-150.

[79] "Pourquoi le physicien, en parlant de la dilatation, etc., d'un barreau d'acier, ne peut-il le considérer simplement sous les espèces que lui fournit le sens commun? Evidemment parce que le phénomène de la dilatation serait alors inexplicable, alors qu'il semble s'expliquer si nous supposons le barreau composé de particules séparées par des intervalles, censés s'agrandir quand le barreau se dilate," Meyerson, *op. cit.*, p. 60. Meyerson adduces this example as evidence that science is explanatory.

laws by emphasizing their logical ancestry in theoretical mathematical formulae, derived from the physical presuppositions.[80]

A theory is not a mere collection of laws. It has an underlying unity which synthesizes the laws into an intelligible system and derives them as its consequences.[81] In this light, a theory may be said to explain laws and laws may be said to describe facts since the function of law is to generalize particular experimental results. This distinction is subject to restrictions. We think that we can explain phenomena by an appeal to laws, just as by an appeal to theory. In the case of theory, however, we have reached into a more ultimate domain. We reach what physics deems to be the logical and mathematical reasons for the laws themselves. In any case, physics is not purely descriptive. It is a science. As such, it seeks after causes, proximate causes by comparison with the ultimate principles studied by philosophy, but causes nevertheless. Confirmation of this point can be had by a perusal of the literature of modern physics and by noting the "because" clauses which are stated or implied in the systematic development of ideas. Moreover, the physicist does not merely describe what happens in a laboratory. He *expects* something very definite to happen on the basis of theoretical notions which he has ahead of time. *To expect* is close to the notion of *oughtness,* or binding force, necessary sequence (in the qualified sense of the word *necessary*). Why does the physicist expect this or that type of result? Because he thinks he knows the causal antecedents of these results, and such causes *ought* to have this or that effect.

But how may we qualify the notion of explanation in physics? Certainly, explanations by hypotheses are not absolute. There are two points of interest in treating this question: a) hypotheses are suppositions with which the effect is consistent; they need not formally be the true causes in themselves; even if they were, they could not, by their very hypothetical character, be known as such; and b) in a system that predicts the real, physics at least in a material sense has come to grips with reality. Taken in its complete form, we can judge theory to be at most consistent with the

[80] Campbell, N. R., *op. cit.*, p. 118.
[81] Bridgman, P. W., *op. cit.*, p. 42; Smart, H., *op. cit.*, p. 127.

effect. Perhaps another formal hypothesis could likewise "save the phenomena."

In discussing this subject, it may be pointed out also that theories tend to account for reality by mechanical entities that differ in degree, not in kind, from the observable data themselves and by mathematical computations that remain in the world of quantity. In explaining the determinants of experience, physics remains on the level of experience itself. The electron, proton, neutron, and other fundamental units into which the macroscopic world has been sundered by modern physics are all determinants of experience. They differ from the macroscopic world only in their size and in their physical properties. As Stebbing has said: "Science has its origin in an attempt to coordinate the facts of sensible experience, but in the discovery of the appropriate type of order, it passes to the consideration of a different order of *facts.*"[82] But the proximate material and motor causes of matter are not sufficient to explain it in the precise sense. Matter, in its entitative character, is unintelligible without form. Efficiency demands final causality to make motion possible. In a genuine explanation, a hierarchy of causes must be recognized. A genuine, satisfying, realistic explanation, one that is in the order of the ultimates though not necessarily ultimate in that order, proceeds from the lower to higher, from the lesser to greater. Such an explanation transcends the world of phenomena. But it is found necessary by the fact that, on intellectual analysis, we find phenomena insufficient to explain themselves.

Similar reservations must be imposed upon the mathematical aspects of explanation in modern mathematical physics. In Meyerson's language, explanation is the process of reducing the multiple to identity. "In other words," he writes, there ought to be, if a phenomenon is to be explained, equality between cause and effect."[83] This identity takes the form of a mathematical equation. Aristotle wrote: "It is the business of the physicist to know the fact and of the mathematician to know the reasoned fact."[84] Mathe-

[82] *A Modern Introduction to Logic,* p. 230. (Italics mine.)
[83] *Op. cit.*, p. 156.
[84] *Post. Anal.* 79a, 1-5.

matics can explain facts when other facts are previously given, and the two sciences, the one, mathematics—a *scientia propter quid* —and the other, physics,—*a scientia quia,*—well go hand in hand as a means of explaining the real. Mathematics, the science of quantity and its relations, is well adapted to the physicist's need for logic and language since physics is concerned with the quantified, mensurable aspects of the universe.

But mathematical theory is a hypothetical explanation of the quantity and not of the ultimate ontological realities in matter.[85] Our mechanical and mathematical interpretations amount to explanations. But if the quantified aspects of matter do not constitute the only realities, neither do the corresponding explanations constitute the only knowledge.

Theories are limited in their truth-content by the fact that they do not reach real causes in the formal sense. The explanatory character of theory must be correspondingly limited. Models and constructs, it was seen, are necessary working principles which have a real foundation but are logically developed into their final form. They are necessary for the birth of mathematical theories, for their application to a physical situation. Both constructs and mathematical interpretations, however, can only render a cause which is consistent with the effects, as far as such antecedent reasons are hypothetical. This provisional character must likewise qualify our judgments on the way in which scientific theories explain. They are only provisional explanations, as was the Aristotelian theory of eccentrics and epicycles. The physicist of the future may find another way to "save the phenomena."

[85] Cf. This is the sense of Meyerson's verdict: "Le signe d'égalité signifie simplement que les choses sont égales par certains côtés ou le seront sous cértaines conventions," *op. cit.*, p. 139.

CHAPTER VII

Physics and the Problem of Proof

Great philosophy, like great literature, survives the age that produces it. Though it deals with the immediate problems of a span of history, it resolves them, in terms that transcend the incidentals of time and place, into the universal principles that man finds always and everywhere. Systems of thought which are bound up with the circumstances of an age perish with these circumstances. Great philosophy lives on.

Thomas Aquinas probed down to the universal truths which dissociate themselves from the incidental marks of his own age. They apply to all times and places. It is not to be a mere *laudator temporis acti* to develop and apply Thomistic principles to contemporary problems. They are not a mere museum of medieval thought. They are still valid today as the penetration into reality of that reason common to all men. But Aquinas did not say the last word for all times on truth and on reality. The principles which he propounded can be deepened, re-interpreted, and re-applied in the light of new facts and new speculations. Truth is one and simple. But this does not mean that it is humanly easy and that we envelop it once and for all in a philosophical classroom. For man, truth is not seen at a glance. It must be progressively deepened and widened in the span of time. Medieval thought assimilated and deepened the timeless principles discovered by the Greeks. Such principles are not ancient, medieval, or modern. They apply to all times. They are timeless. But each age is called to re-apply and re-explore their vast riches in the light of their organic, dynamic character. That is what is meant by *philosophia perennis*.

Philosophy is problem-solving. There must be problems before there are answers. Living at a time when empirical science had not yet acquired its autonomy—for specialization even in physics is always but a sequel to a general system—Aquinas found no need to elaborate a formal logic of induction. The empirical sciences were treated in the philosophical synthesis. The logic of the two disciplines was not separated either. Inductive logic was not unknown either to Thomas or his contemporaries. His commentary on the *Posterior Analytics,* though principally concerned with the science of demonstration in the strict sense, is replete with direct answers to problems in logic that are sometimes thought to have arisen in the modern age. Finally, because they are timeless principles of all human thought, Thomistic principles enable us to erect a critique of the method of physics, just as the dateless cosmological principles of Aquinas enable us to assess philosophically the empirical discoveries about the material world.

The first problem, in appraising the method of physics, is to define the scope of the science. It has already been argued that modern physics is an intermediary science. It is formally mathematical because it is a science of measurement. It is materially physical because it is a physical subject-matter that is measured. Aquinas insists time and again on the correct notion of an intermediary science and on the observance of the limits which its formal object prescribes.

Pure mathematics considers its object as abstracted from matter. Such a science is pure geometry or pure arithmetic; one may also add pure mathematical analysis (the calculus). But knowledge can also be derived from the application of mathematics to material things. This is the case with astronomy or harmonics where experience or experiment supplies material for mathematical interpretation.[1] Another example of an intermediary science is the application of geometry to the science of perspective. Here we have mathematics applied to the study of physical lines.[2] The subordination of one science to another in this way corresponds to two questions that may be asked about an object: if it is (*quia*); and why it is (*propter quid*). The answer to the first question is provided by the lower of the two sciences which combine to form an intermediary science; the higher science is concerned with the second question.[3] Aquinas applies this viewpoint to a mathematical

[1] *In I Anal. Post.* 24.
[2] *In I Anal. Post.* 39.
[3] *In de Trin. Boeth.,* q. 5, a. 1, ad 5.

treatment of physical problems, as Aristotle had done before him.[4]

In such a concept of the hierarchy of the sciences, a discipline which provides the point of view for one science may in turn form the subject-matter for the science immediately above it. This is the case with perspective which is interpreted by geometry from one point of view and from another point of view interprets such phenomena as rainbows for the experimental physicist.[5] Aquinas is careful to point out that the subject-matter and the point of view assumed by the student are not in the same genus.[6] He insists that mathematics is the science of idealized quantity.[7] The world of real, quantified being on the other hand is the physical world. It may be studied in the light of so-called physical abstraction which prescinds only from the individuating characteristics of beings but not from the sensible material which they have in common. In an intermediary science which is mathematical in viewpoint on a subject-matter that is physical, the mathematical treatment is, as pure mathematics, on a different level from the subject matter.[8]

It follows immediately from the foregoing that mathematics does not exhaust the knowable universe of matter but remains extrinsic to its nature, as a *universe of matter.* If relativity theory and quantum mechanics are tending more and more to geometrize the world of mobile being, to reduce their accounts of the universe to the world-lines of the space-time continuum or to the position and velocity co-ordinates of wave-particles, the commentary of Aquinas on the *Posterior Analytics* provides a realistic basis for assessing the character of this new physics. It is unusual that Aquinas, in illustrating the *scientiae mediae,* should himself have so often used examples from geometry. These can be applied almost literatim to contemporary physics. "If indeed," Thomas writes, "things are the same by nature but are considered in the light of different principles, they pertain to different sciences. A mathematical body is not something separated from a physical

[4] *In Anal. Post.* 24.
[5] *In I Anal. Post.* 14.
[6] *Ibid.*
[7] *In de Trin. Boeth.,* q. 5, a. 3.
[8] *In I Anal. Post.* 14.

body. Still because a mathematical body is known through principles of quantity and a physical body through principles of motion, the science of geometry is not the same as physical science."[9] A science, Aquinas says, does not deal with any accidents whatsoever but only with those that come within the compass of its method. If geometry studies physical lines, it cannot pronounce on any of the principles associated with the lines in the physical world as physical. It applies to lines as lines.[10] Aquinas warns time after time against what Dr. John K. Ryan has called the fallacy of "alien method" whereby the method of one science is transferred to another science.[11] Every science has its proper questions, its proper answers, and its proper method.[12] No science may demonstrate conclusions in another.[13] In the case of sciences which are subordinated to each other, the formal object interprets the material object. Aquinas points out that, for example, arithmetic, a higher science, may deal with geometrical magnitudes, a lower science, from the arithmetical point of view.[14] But in this procedure, arithmetic remains arithmetic. It does not become geometry. It cannot prove geometrical principles. In the same way, mathematics applied to physics does not become physics. Geometry does not become an experimental science. *Diversorum enim diversa principia sunt.*[15]

In the opinion of Aquinas, the intermediary sciences are more mathematical than physical in their mode of explanation.[16] But they are physical in their foundations.[17] Applied to modern physics, this distinction means that mathematical physics is a science which relates the geometrical aspects of the phenomenal world. Its method is limited in point of view to the metrical. Though it is highly mathematical as a result, it still deals fundamentally or materially

[9] *In I Anal. Post.* 39.
[10] *In I Anal. Post.* 14.
[11] Cf. also Aquinas, *ibid.*
[12] *In I Anal. Post.* 20.
[13] *Ibid.*
[14] *Ibid.*
[15] *In I Anal. Post.* 41.
[16] *In de Trin. Boeth.*, q. 5, a. 3, ad 6.
[17] *Ibid.*

with the real world, not with the world of abstract mathematics. To apply this method to other fields of knowledge either by denying material foundations, in the manner of Eddington and Jeans, or by seeking in physics itself to interpret the internal constitution of the subject-matter, in the manner of philosophy, is to commit the error in the beginning of the knowledge process which can lead to grosser errors in the end.[18] There is a maxim in orthodox psychology: *psychologica psychologice traduntur*. Analogues of this may be applied to philosophy, physics, and mathematics.[19] Each should be treated in its own way.

Method, as the Greek parentage (μέτα ὀδός) of the English word suggests, is a way toward an end. The schoolmen, seeking the ontological truths behind the phenomena of sense, used a corresponding method. Induction was not unknown to them, even to Duns Scotus and Aquinas, the greatest of their metaphysicians. Though attaching various meanings to the word *inductio,* Scotus seems to have come to a genuine solution to the problem of induction. He pointed out that we can generalize from the repeated occurrence of phenomena to a universal principle. The regularity in the effects of necessary causes (which operate in nature) indicates that the effects are the natural results of such causes. They will therefore follow always and in all cases from such causes.[20] Aquinas, though not so striking in his vocabulary, laid down clear principles that might be used to interpret induction as applied in contemporary physics. His system—an organic thing which can ingest the truth wherever it is and assimilate it[21]— clearly leaves room for modern scientific induction while prescribing rules to avoid its errors.

Aquinas uses the word *inductio* to describe the abstractive operation of the intellect in reaching the universal from a sensible cognition of singular things.[22] He draws a contrast between induction and demonstration and points out that the universals reached through the former process furnish the premises of the latter.

[18] *De Ente et Essentia,* c. 1.
[19] *In I Anal. Post.* 20.
[20] *In I Sent.*, d. 3, p. 4, a. 2.
[21] Maritain, J., *Sept Leçons sur l'Etre,* pp. 17 ff.
[22] *In Anal. Post.* 29.

Traditional philosophy is not a completely deductive system. It begins in sense experience, Aquinas avers, otherwise it would not be scientific. Though universals are above space and time and in themselves are purely intelligible, they are known through induction.[23] Aquinas held firm to his reasoned realism on this point against the Platonism of his time which, by its essentialist metaphysic and its a priori, systematic character, suggests modern physical theory in more than a passing way. Genuine philosophy provides the only genuine, self-sufficient induction. Proceeding either directly through abstraction or through the equivalent of this direct abstraction (viz., reaching general principles through a reflection on nature's order) philosophy and not physics can keep induction on solid ground and give the necessary support to the conclusions of physics. Abstraction is not dreaming; it does not falsify or negate. Abstraction, the passing from singular to general, proceeds *per viam inductionis,* by induction from sense data.[24] Physicists are often unaware that whenever they think, as men, they are using this very abstractive power which Aquinas describes; they are unaware that knowledge is not empirically given as though pre-formed but must be wrested from nature by the application of thought to the data which are given. The whole of reality is not actually given. If it is, we might as well close our laboratories and destroy our literature. We are scientists, or rather would be, by simply opening our eyes if everything is given.

Thomas developed his doctrine of abstraction from the texts of Aristotle who wrote that it is "impossible to come to grasp universals except through induction. But induction is impossible for those who do not have sense perception."[25] Aristotle in turn acknowledges that induction goes back to Socrates.[26] In Plato, there are numerous examples of the Socratic method of definition.

[23] *Ibid.*

[24] *In II Anal. Post.* 20.

[25] *In I Anal. Post.* 81 b 5; cf. also *Top.*, A, 12, 105 a 13; *Eth. Nic.* Z, 3, 1139 b 28; A, 7, 1098 b 3; *Anal. Pr.* B, 21, 67 a 23. "Partir de l'expérience pour aboutir au concept, sélon Aristote est induire," de Corte, M., *La Doctrine de l'Intelligence chez Aristote*, Paris, 1934, p. 138.

[26] *Met.* XIII, 4, 1078 b.

It is a method of considering examples with a view to arriving at a definition.[27]

In the *Meno,* Socrates attempts to define virtue by his inductive method, eliminating all other attributes of virtuous persons until the common notion of virtue remained.[28] Plato elaborated on this method even further. He introduced the conceptual development of ideas. He proposed considering also "not only the consequences which flow from a given hypothesis, but also the consequences which flow from denying the hypothesis."[29] By a process of eliminating the false and the accidental, as in the case of defining virtue, a knowledge of essence can be reached.

Francis Bacon, it was already noted,[30] compares his method of induction, by exclusion, to the Socratic method of definition. As it was also noted, however, the Socratic method is based upon an intellectual analysis of being and not merely upon a merely mechanical juxtaposition of sense data. Plato's logic also prescribes a classification or division (διαίρεσις) of concepts by a method of dichotomy.[31] This suggests Bacon's catalogues of instances. But Plato points out that definition precedes division, because "the right way is, if a man has first seen the unity of things, to go on with the inquiry and not desist until he has found all the differences contained in it which form distinct classes."[32] This is the converse of the Baconian method which, having ruled out intellectual analysis, must make division the first step and definition only the second.

Thomas points out the short-comings of mere exclusion and mere division—things that Bacon later naively accepted. Following Aristotle, he recommends the Platonic method of definition. If we want to prove, he writes, that a wall does not breathe simply be-

[27] "The higher ideas, my dear friend, can hardly be set forth except through the medium of examples . . . ," *The Statesman,* in *The Dialogues of Plato,* trans. B. Jowett, New York, 1937, vol. 2, p. 304.

[28] *Meno,* in *op. cit.*, vol. 1, pp. 350 ff.

[29] *Parmenides,* in *op. cit.*, vol. 2, p. 97.

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

[31] *Phaedrus,* in *op. cit.*, vol. 1, p. 267; *The Statesman,* in *op. cit.*, vol. 2, p. 312.

[32] *The Statesman,* in *op. cit.*, vol. 2, p. 313.

cause it is not an animal, we do not attain to true causes and reasons.[33] We must know beforehand something of the essence of the phenomena in question if we apprehend the *why's* as necessities of being.[34] Perhaps, Aquinas adds, there may be animals that do not respire. In the method of division, Thomas followed Aristotle who, in turn, insisted with Plato on the deductive character of the process. In this principle, one finds ample argument against the pure induction of Francis Bacon in his catalogue of the Natural and Experimental History of Phenomena, the beginning of classification, and in his Tables, the end of the same operation. Through division alone, Aquinas notes, we cannot reach essences.[35] If it is said that man is either pedestrian or aquatic, it does not follow that since he is not aquatic he represents all that we mean when we say *pedestrian animal*.[36] We must know that *animal* is sufficiently divided as either pedestrian or aquatic. We must therefore know something of the nature of animal. We must know this so that it does not matter "whether the same method is used in many or few cases. The essence is the same in all."[37] Merely to note that man is pedestrian does not justify the view that his nature is such.[38] Necessary division is deductive and intellectual. These two properties insure that a correct order can be observed in the division and that only essential principles of division will be considered, not the accidental differences which may or may not be present.[39]

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[33] *In I Anal. Post.* 23.

[34] In this argument, Aquinas was relaying on the biological theories prevalent in his day. He states that the conclusion of the argument does not follow, since there are animals like fish which do not breathe. In the concept of animal, then the idea of respiration is not necessarily included.

Obviously, experimental facts have since contradicted the facts known to Aquinas himself as to the nature of fishes. But such new discoveries have not contravened the logic which insists on the intellectual analysis of quiddities in division and proof and which can be so tellingly applied to modern physics.

[35] *In II Anal. Post.* 4.

[36] *Ibid.*

[37] *Ibid.*

[38] *Ibid.*

[39] *In II Anal. Post.* 15.

This logic of division is not without direct bearing on the problems of modern science. In the classical system, matter and radiation were by and large fenced off into two inseparable domains. Quantum physics has brought them together. Yet, because in physics we do not know essences, is it not possible that our present classification of mechanical and optical phenomena may again be revised? The theory of relativity may make it possible to combine gravitation, electricity, and electromagnetism into a single mathematical treatment. But this does not mean that the phenomena are the same in their ontological status, apart from their mensurable aspects. Do the facts of symmetry and anti-symmetry in the treatment of quantum mechanical problems of wave-particles express deep, essential differences between the phenomena in question? Or can we say that one element in the periodic table differs from another simply by the addition of electrons in the orbits, i.e., of protons in the nucleus? Scientific method in itself does not reach essences and therefore cannot make essential definitions and divisions. It can only define and divide according to mensurable properties of the corporeal world which in themselves cannot be accepted as the signs of deeper, essential, really and truly ontological differences between things. Since scientific technique does not pierce down to the essences of things, which are intelligibly and not empirically attainable, its division and classification must suffer correspondingly. Division of itself does not constitute syllogistic necessity, Aquinas argues, because it leaves unanswered the question of *why* the conclusions are necessary.[40]

On the other hand, deductive division from previously abstracted notions is a way of arriving at true definition.[41] The reason is, as Aquinas indicates, that such a division is based upon common notions (essences) in which the subgroups are perceived in their relation to the whole class. The human spirit passes from the common to the special and not, after the manner of English empiricism, along the opposite path.[42] We cannot make an essential division in proceeding from the special to the common. But having attained the common, universal, and essential, we can see its rela-

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[40] *Ibid.*

[41] *In II Anal. Post.* 15.

[42] *Ibid.*

tion to the members. Only so far as we do this can we make essential divisions and classifications.

Aquinas approaches from another viewpoint the problem of division and definition by showing their inductive origins. In the process of *inducing* the definition of things, as he puts it, essential differences must be taken into account in dividing one thing from another. Thomas adds that this movement is from the less common to the more common.[43] It is an aid to teaching which should begin with familiar instances. It is also a noetic necessity. The mind can advance in true knowledge only from the known to the unknown. But this is, from a logical viewpoint, induction in the sense of abstraction. The mind grasps the essences of things, then compares and relates the genera and species.

As a case in point, Aquinas borrows an example from Aristotle. Suppose that we are searching for a definition of heroism. We will examine individuals who are heroic and attempt to discover their common characteristics. We examine Hercules, Ajax, and Achilles. We find that they would not tolerate wrongs. We examine Lysander and Socrates and find that they were unaffected by hardships. They bore them as they would good fortune. We conclude then that heroism consists in an indifference to good or bad fortune and an intolerence of wrongs.[44]

This process is the Aristotelian ἐπαγωγή. Aristotle, it is true, did not employ the word in this passage. Neither did Aquinas use the word *inductio* in his commentary. But ἐπαγωγή in Joseph's words "has come traditionally to be called the method of obtaining definitions by induction."[45] From the use of the term *inductio* elsewhere in Aquinas, it is clear that the Socratic method of definition was one of the senses he gave the word. Such a process begins in sense. It examines individuals. But it is intellectual and abstractive.[46] Any other method of division, any other method of

[43] *In II Anal. Post.* 16.

[44] *Ibid.*

[45] Joseph, H., *op. cit.*, p. 379.

[46] For Aristotle's notion of induction as abstraction, cf. de Corte, M., *op. cit.*, pp. 179 ff. "Elle ne peut donc être qu'une saisie immèdiate de l'universel dans le particulier," p. 180.

In commenting on this ἐπαγωγή, as Aristotle conceived it, Joseph says that it leads to an "inductively obtained *conclusion*" and adds that "the

classification, does not attain to essences, does not attain to necessity. Modern physics certainly does not meet these requirements. It divides, it defines, only as it measures, and measurement, a strictly empirical operation, stays strictly on the empirical level. It does not encompass essences. It does not reach the unchanging and the necessary.

The attitude of Aquinas toward experiment showed that he viewed induction as an abstractive operation. After an herb, for example, has been found by test, he declares, to have cured many men of fever, it can be accepted as a principle of art and science that the herb actually cures of fever.[47] Aquinas has merely applied here what Bacon later called the Table of Presences and what Mill formulated as the Method of Agreement. Yet our modern use of the term *induction* may befog the real meaning of this passage in the mind of Aquinas. Here too, he does not use the word *inductio;* but it is clear from his discussion of experiment that his method bears a striking resemblance to modern scientific technique. What is noteworthy, however, is that he does not believe

conclusion is certainly "syllogized," so that the *conclusion* may be what is "induced." It has, however, also been thought that the process of bringing up or citing instances, by means of which the conclusion, is to be established, is what the word was primarily intended to signify. (Bonitz, *Index. Aristotel.*, s.v. ἐπαγωγή, seems to take this view); and anyway the process described is one in which a general *conclusion* is established by citing the instances of its truth," *op. cit.*, p. 378, note. The word *conclusion* raises the problem of whether the ἐπαγωγή, developed from the Socratic method, is a process of abstraction or the result of a so-called inductive syllogism. Yet so long as we have only individual instances, we cannot infer a universal conclusion according to the laws of logic. *Aut semel aut iterum medius generaliter esto.* We can only arrive at a necessary medium through the process of universalization which is abstraction. Here we are face to face with the central problem of induction. The gap between the singular and the universal can only be bridged over by abstraction, not by enumerating singulars as though they could eventually form an adequate medium or middle term. Hence, Aristotle remarked that the process of induction does not have a middle term, and Aquinas noted that there was no medium between the individual and the species. Thomas' example then, like Aristotle's—since an adequate middle was lacking—does not seem to be a reasoning process but only a more elaborate form of abstraction. To say, as does Joseph, that the "conclusion is certainly 'syllogized' " is misleading.

[47] *In II Anal. Post.* 20.

he is using an inductive "argument." He refers to the process as though it were an elaborated abstraction. The procedure, he remarks, "occurs through the possible intellect which, in turn, works by means of the active intellect which renders things actually intelligible by the abstraction of universals from singular cases."[48]

This process of abstraction liberates essences (known either in themselves or else, as in Thomas' present example, through effects) from their material surroundings and enables us to generalize our conclusions. The operation of abstraction depends on insight, not on formal reasoning, though afterwards we may revert to logic to justify the conclusion we have reached. Such a logic in fact was treated at length by Aristotle in his *Topics,* which deals with dialectic in the Greek sense and which prescribes, in the course of discussing disputation, ways of justifying principles arising through abstraction, hence not formally demonstrable. Dialectic in this sense is not formal logic. In the case of Aquinas' example, we should have to appeal to the regularity of the event and the regularity of nature to justify, against attack, that it is in the nature of this particular herb to cure of fever. In this respect, Thomas' example pertains to reasoning. He himself does not mention this fact. On the contrary, he states that the "conclusion" is a principle known by intellection and not through the termination of a process of discursive reasoning. The process seems directly to involve only apprehension, without recourse to argument in the syllogistic sense.

It is characteristic of the firm realism of Thomistic philosophy that the commentary on the *Metaphysics* of Aristotle should open with the discussion of the importance of experience as the beginning of knowledge. Experimental conclusions, declares Aquinas, arise from the memory of singular events which are collected and perceived as true by the cogitative interior sense in man, subordinated as it is, to the intellect's power for grasping intelligible and universal essences.[49] In addition to mere sense experience, Thomas says, man has universalizing reason by which he perceives the

[48] *Ibid.*

[49] What Aquinas, following Aristotle, says here pertains more to the psychology of discovery than to the logic of proof.

essences of things.[50] It is clear that knowledge begins in experience. But it is also clear that even experimental conclusions involve abstraction. It is ultimately through insight that the discrete data can be unified into a universal conclusion.

The role of abstraction in the life of reason, whether it be on the scientific plane or in the syllogistic arguments of philosophy, cannot be overestimated. Necessity is not found in mere regularity of sequence. Aquinas pointed this out long ago when he wrote: "Discovery is not always associated with certitude." Necessity does not rest on mere *is-ness* of relationships. It is rooted in their *must-ness.* A conclusion is said to be necessary when it cannot possibly be otherwise.[51]

Since the conclusion of an argument cannot be otherwise than it is, every valid argument must be reducible to first principles. The principles of identity, of non-contradiction, and of excluded middle are immediately evident from the notion of being. They constitute our first judgments about being. They flow from the notion of being without the mediation of the middle term of demonstration. Aristotle and Aquinas refer to them as the first, the true, and immediate principles which are self-evident.[52] They are seen in the very idea of being itself which is abstracted as the initial idea of the intellect.

But abstraction, as related to proof, does not stop here. The material as well as the principles are grasped by abstractive, intellectual insight into reality.[53] By apprehension, the intellect pierces to essences, whether known perfectly or through effects, of the things whose accidents are presented to the senses. It is this knowledge of essences which warrants the judgment that a thing cannot be otherwise than it is. The contingent, spatio-temporal, existential determinations of the material world make this type of certitude impossible on the level of phenomena as such.[54] Hence, demonstration is not attained by an enumeration of individual instances (the *inventio* referred to above). It is only possible by ascending

[50] *In I Met.* 15.

[51] *In I Anal. Post.* 1.

[52] *In I Anal. Post.* 3.

[53] *In II Anal. Post.* 1.

[54] *In I Anal. Post.* 14; I, 86, 4; *In de Trin. Boeth.,* q. 6, a. 1.

beyond the changing matter of time and space to the realm of unchanging universals. "Things are contingent," says Aquinas, "because of their material components; because contingent things can be or not be. Potentiality pertains to matter; necessity springs from form; because those things which spring from form are necessarily present."[55] Form and quiddity (essence) are bracketed together by Thomas.[56] Both are used to signify that which makes a thing what it is. Definition indicates form or essence.[57] If therefore we seek the roots of absolute necessity in nature, it is to the form or essence that we must penetrate. It is form or essence which makes a thing so that it cannot be otherwise. If it were otherwise, it would no longer be the same thing. Man could never be irrational and could never be a non-animal. He could not then be a man. An irrational man is a contradiction. Man cannot be a man and be other than he is. Through knowledge of essences,[58] we can see the connection between the subject and attribute in the premises. We see it as necessary and universal. The necessary conclusion follows from such premises as a necessary effect. The attributes, predicated of the subjects in the premises, are seen to be contained within the very definition of the subject. This intellectual insight is the ultimate work of abstraction, apprehending the quiddities of things.[59]

In view of the importance of abstraction, Aristotle, and also Aquinas in his commentary, commences the *Posterior Analytics* with a discussion of the foreknowledge required in demonstration.

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[55] I, 86, 3.

[56] *De Ente et Essentia,* C. 1, Lect. 2.

[57] *In I Anal. Post.* 9.

[58] It is not necessary here to enter into a digression on the type of knowledge which we have of specific essences. This has been treated by Adler. M., *The Problem of Species,* New York, Sheed and Ward, 1940 (*passim*); and by Maritain, *op. cit.,* pp. 411 ff. Essential connections, as far as they are necessary, involve the problem of species in the material order in oblique fashion; essential, necessary, universal connections are rooted in being which is neither a genus nor species but is transcendental. Necessary judgments about material realities can be made once we attain to being, and we do that in the first intellectual experience we ever have. Only in so far as we reduce our knowledge of material realities to necessities of being is this knowledge necessary in character.

[59] *In I Anal. Post.* 1.

We cannot demonstrate everything. That would constitute a regression into infinity. We must commence with the self-evident, known through abstraction and seen to be necessary by its very definition.[60] Both Aristotle and Aquinas insist on definition as a preamble to demonstration.[61] Both distinguish two fundamental types of demonstration: a) causal demonstration (*demonstratio proper quid,* διοτὶ ἐστὶν) which demonstrates effect from cause and gives the reason why the attribute is necessarily predicated of the subject; and b) factual demonstration (*demonstratio quia,* ὅτὶ ἐστίν) which demonstrates cause from effect and merely affirms the necessary inherence of the predicate in the subject without being able to give a sufficient reason as seen in the subject itself.[62] In both types of demonstration, definitions are required. In causal proof, we must know what the subject is and whether it exists; we must also know what the accident is, though not whether it is, since this is to be established.[63] In the case of factual proof, since the existence of the subject must be proved, the question of what it is is preceded by the question, whether it is. The existence is proved from accidents. Here, however, we know of the subject what its name stands for.[64] In the factual demonstration, we must again know of the predicate what it is but not whether it is, exactly as in causal proof. Since, however, as Aquinas says, all demonstration begins with abstractions from the existential world of sense, the existence of the predicate is known at least in parts from some other subject. We cannot know essences unless we have first apprehended as well the existence of some subject.[65]

Aristotle and Aquinas point out that science is the search after a middle term.[66] This is known from the definition of the subject and the definition of the predicate. Because they consort

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[60] *In Anal. Post.* 9.

[61] *In I Anal. Post.* 4.

[62] This does not mean that there is no sufficient reason in the subject but only that the sufficient reason, not being seen from the subject out, must be known from the effect rather than the cause.

[63] *Ibid.,* cf. Bennett, O., "St. Thomas' Theory of Demonstrative Proof," in *Proc. Amer. Cath. Phil. Assoc.,* 1941, pp. 76-88; *In I Anal. Post.* 1.

[64] I, 2, 2 ad 2.

[65] *In I Anal. Post.* 30.

[66] *In II Anal. Post.* 1.

in the middle term, they are united in the conclusion of the demonstration.[67]

It is rightly then that Aquinas refers to definition as the medium of demonstration.[68] If science is the knowledge of causes, the middle term is the cause which makes science possible.[69] It is thanks to definition that Aquinas can say that before the conclusion is actually drawn, it is known in some way since it is contained causally or potentially within the singular cases from which it is drawn.[70] Abstraction then, by which the mind grasps first principles and lays hold of the subject, predicate, and medium of demonstration, is an indispensable tool of the reasoning process. Without it, science would be impossible. For it could not compare and correlate the individuals of the sense world as individuals since every individual as such is unique and incomparable. It is small wonder then that we look in vain for a pure system of positivism.

The traditional concept of insight by abstraction has been lost by those modern thinkers who attempt to reason from mere collections of data and who base their conclusions on the enumeration of instances. For Aquinas, intellectual insight is a way to the nature of things which, under penalty of contradiction, cannot vary while remaining the same nature. Once the nature of a thing is gripped by man's intellect, he can then demonstrate its essential or proper interrelationships in a way that "nothing can be more certain than that the opposite is false."[71] There is no science of the purely incidental. Without corrupting the subject, incidental things can be or not be present.[72] Through abstraction, insight into form or essence, we discern whether a predicate is a separable accident or a proper one, which, while not being part of the essence of a thing, flows necessarily from the essence. If we were ignorant of the essences of things, we could not judge whether the predicate, as a qualification of the subject, was separable or not.[73] No attribute

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[67] *In Anal. Post.* 4.
[68] *In I Anal. Post.* 26, 30; *In II Anal. Post.* 9.
[69] In *II Anal. Post.* 9.
[70] *In I Anal. Post.* 2.
[71] *In I Anal. Post.* 5.
[72] *In I Anal. Post.* 31.
[73] *In I Anal. Post.* 36.

can be defined without the definition of the subject from which it flows and of the relations, proper or incidental, which it bears to the subject.[74] Just as the premises of demonstrative proof employ necessary interconnections among the subject, the middle term, and the predicate, so in the conclusion the dependence of the predicate on the subject is not incidental but proper, i.e., necessary.[75] *Demonstratio est ex necessariis et de necessariis.*[76] Aquinas sums up his doctrine on the nature of scientific proof by affirming, with Aristotle, its universal and necessary character: "For science does not treat of the singular cases which fall under the senses. . . . And another character is that science deals with the necessary, that is, with what cannot be otherwise."[77]

In this chapter, it was seen that contemporary physics is an intermediary science that is physical in its subject-matter and mathematical in its viewpoint. Induction as an abstractive process was examined and related to the problem of definition and division. It was seen that physico-mathematical science, since it does not employ abstraction as a formal principle of method, does not attain essences, whereas philosophical induction does. It follows that since abstraction is necessary for strict proof, physics does not reach the premises necessary for genuine demonstration. Such an office belongs to philosophy, which employs intellectual analysis on the same subject-matter that physics measures and correlates.

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[74] *In I Anal. Post.* 1.
[75] *In I Anal. Post.* 9, 30.
[76] *In I Anal. Post.* 13.
[77] *In I Anal. Post.* 42.

CHAPTER VIII

Law, Theory, and Logic

Induction in the philosophical sense is abstraction. When Aquinas drew his frequent contrast between induction and the syllogism, he meant induction in this sense.[1] In the same trend of thought, demonstration is contrasted with induction.[2]

Aristotle employed the word induction (ἐπαγωγή) to characterize the process of establishing a general proposition by affirming its truth in each particular case. To take Aristotle's example: Man, the horse, the mule are long-lived. Man, the horse, the mule are bileless. Therefore, all bile-less animals are long-lived.[3] In this argument it is at once apparent that the middle term is not distributed. But Aristotle himself was aware of this. He takes it into account by insisting that the enumeration must be complete, must embrace all bile-less animals, if the argument is to be formally valid. In such an event the minor can be converted into the proposition, all bile-less animals are the man, the horse, the mule. Hence, the argument becomes formally correct. Aristotle thus conceived of the inductive syllogism, as it is called, as induction by complete enumeration, a fact that drew sharp criticism from Francis Bacon.

From criticism on this point, Aristotle cannot wholly be exonerated. If we grant that by complete enumeration, the minor premise can be converted and the argument can become *formally* valid, still from the point of view of material logic, there are three objections to the process: a) how can we overcome the tremendous practical difficulty of counting all the instances of a middle term; b) how can we be sure that our enumeration is complete even spatially, let alone temporally and with regard to future samples; c) finally, the conclusion in an individual case must be affirmed experien-

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[1] *In I Anal. Post.* 1, 21.
[2] *In I Anal. Post.* 7.
[3] Ana. Prior III, 68 b 15 ff.

tially before it can be drawn from the inductive process. The whole argument therefore is sterile. It cannot give rise to new knowledge because the conclusion of the individual cases is already foreknown. Mill's attack on the syllogism is based on a misconception of what Aristotle and Aristotelians hold. But applied to the enumerative induction of Aristotle, the arguments carry weight.[4]

Aquinas noted the weakness of enumerative induction. He points out the necessity of subsuming every single instance under a purely enumerative generalization. *Oportet supponere quod accepta sint omnia quae continentur sub aliquo communi. . . .*"[5] If we argue, for example, that Plato, Socrates, and Cicero are running, we cannot generalize this fact to include all men.[6] Running is an incidental thing. The mere enumeration of instances (*via inventionis*) does not disclose the nature of the being in question. So long as we are ignorant of the type of connection between subject and attribute, we must allow for the possibility that the next instance we examine will be at variance with the foregoing.[7] Not every predicate indicates the essence of the subject, Aquinas declares, nor does it reveal how the attribute is ordered to the subject.[8] It was Aquinas, long before Bacon and Mill who said against purely enumerative induction: "He who passes by induction from singulars to universals neither demonstrates nor syllogizes in a necessary way."[9] Thomas laid down two characteristics of a universal: the attribute must be contained within the subject, no matter how the subject may be qualified in other re-

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[4] In addition to enumerative induction which terminates in a *collection* of individuals, Aristotle recognized another way to general principles. It is the method of induction, considered as abstraction; for "there is an originative source," he writes, "which enables us to recognize the definitions," *in I Anal. Post.* 72 b 20. Whatever may be said about enumerative induction does not pre-judge the syllogism; Aristotle conceived man as endowed with the intellectual power to see in one lone example of being truths that apply to all being.
[5] *In II Anal. Post.* 4.
[6] *Ibid.*
[7] *Ibid.*
[8] *In I Anal. Post.* 10.
[9] *In II Anal. Post.* 4.

spects;[10] it must be contained in the subject independently of time.[11]

The principles which Aquinas found in being and in our ways of knowing it can be aptly applied to the method of physics. Physics is governed by these principles as much as philosophy. They govern the correctness of thought and the firmness of certitude. Such laws were not fabricated by Aquinas nor by Aristotle nor by the tradition which both represent. They are dictated by the nature of being and by the nature of human knowledge. Philosophy does not accept the argument from authority. Its sole guide is reason. Scientific method must be submitted to examination by philosophy, not because it is Thomistic or Aristotelian philosophy, or Kantian or Cartesian. Reason itself imposes standards by which the method must be judged.[12] There are two paramount questions involved in the critique of method in physics: the question of law and the question of theory.

A law, as it was already observed, is a generalization of empirical fact in physics. In view of the short-comings of purely enumerative induction, a crucial problem, in Campbell's words, "arises from the necessity that the relation established by a law shall be valid, not only for that portion of experience on which the evidence for the law is based, but also for experience received subsequently and known at the time of establishment."[13] So long as our knowledge of the past rests upon a mere regularity of occurrence, we cannot, on the level of empirical science, conclude to a similar regularity in the future. If the middle term is a particular or a mere collection of particulars, we cannot draw a universal conclusion.[14] Even if we did, it could contain nothing new. Though necessary truths can be drawn *from* contingent things by abstraction, necessary conclusions cannot be the result of con-

[10] This principle suggests Newton's third rule of the Rules for Philosophizing, cf. *supra*, p. 74. However, Aquinas was speaking of genuine universalization through an abstracted knowledge of essences. Newton was speaking of generalization through enumeration.
[11] *In I Anal. Post.* 8.
[12] Cohen and Nagel, *op. cit.*, p. 278.
[13] Campbell, N. R., *op. cit.*, p. 89.
[14] *In I Anal. Post.* 7.

tingent media as far as they are contingent.[15] Built on a middle term abstracted by the intellect, demonstration is not made more certain by merely multiplying the number of contingent media.[16] For the universal itself is not a mere summation of instances.[17]

These principles have a direct bearing on modern physics. Law is empirical in physics. Physics deals with the world of sense, where a knowledge of intelligible essence is precluded by the scientific method itself. Necessary truth, it has been noted, demands the ascent of the mind to essences abstracted from their immersion in matter. By a simple enumeration of the singular cases of the sense world, how can we know, Aquinas asks, that an attribute can be predicated in all possible cases and that no contrary instance is possible?[18] If induction of law in physics depends on mere enumeration, a mere solitary contrary instance can disprove it.[19] On the contrary, a knowledge of universal truth rests not on sense but on intellectual insight.[20] It is always and everywhere present in a thing as a result of the thing's nature.[21] Everywhere and always man is a rational animal; motion demands a mover; being demands order. Otherwise man would no longer be man, nor motion motion, and so on. The nature is seen by insight, not by counting. Here it differs from a mere collection. It is only in modern times that the emphasis has been placed not upon nature but upon number. D'Abro, for example writes: "In short, it is in the accuracy with which the facts are studied and co-ordinated, and it is in the number of facts considered, that the scientific method differs from all other methods. Therein rests its superiority."[22] But no matter how accurately a ratio expressed by law may be measured or how numerous the ratios may be, reason does not leave room for an immediate, empirical conclusion to the necessity and universality which are the characters of science.

[15] *In I Anal. Post.* 8.
[16] *In I Anal. Post.* 21.
[17] *In I Anal. Post.* 10.
[18] *In II Anal. Post.* 5.
[19] *In I Anal. Post.* 12.
[20] *In I Anal. Post.* 40.
[21] *Ibid.*
[22] *Evolution of Scientific Thought from Newton to Einstein*, p. 384.

The mere multiplication of instances, no matter how conditions may be varied in accordance with such requirements as the five canons or Newton's third rule, does not constitute an adequate medium for demonstration, does not include knowledge of the whole compass of the species, "since no medium can be found between the individuals and the species."[23]

If no such medium exists, then the passage from the individuals to the species, involves a gap between two different orders. It is precisely this gap which abstraction bridges over. From the singulars of the sense world, it disengages the universal notes. Once these are attained, we know in advance that every middle term of the same type (*species*) will embody them. We do not count instances. We analyze them. There is new knowledge and not a sterile process. Our knowledge is such *ut non oporteat ulterius medium quaerere.*[24] Cohen and Nagel write in a similar vein: "Consequently, universal propositions may be safely applied to an actual subject matter only in so far as we are thoroughly familiar with the *type of object* of which the actual case is a *sample*."[25] Attempted definition of a universal from a mere enumeration of singular cases in which it is found leads to an infinite regress. There is no limit to the number of such individual cases. The infinite series cannot be bridged over by enumeration, so such a definition becomes impossible.[26] When we cannot have definitions, we cannot have science.[27] But the "series," if one may continue

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[23] *In Anal. Post.* 1.

[24] *Ibid.*

[25] *Op. cit.*, p. 280-281.

[26] *In I Anal. Post.* 32.

[27] Dantzig cites an example that may seem to validate enumerative induction as applied even to infinite aggregates: ". . . *any mathematical method of demonstration applicable to infinite aggregates is but a complete induction in disguise*. . . . In the words of David Hume, *it rests on our belief that the future will resemble the past*," *Aspects of Science*, pp. 111-112. This statement describes the procedure of the calculus which is fundamental to the mathematical physics of modern times. But such a procedure is not only inductive. Integration is possible only on the basis of a knowledge of the region that lies between the limits of integration. Hence, Aquinas' argument still holds.

Mathematical induction, even in such rather pure cases as the bi-nomial theorem or determination, by tests, of the convergency or divergency of

to use a mathematical term, *can* be bridged. The method is of a different sort from the empirical. It is the method of abstraction by which the mind passes from sense data to the higher order of intelligible essences.

Physicists overcome, to an extent, the difficulty of traversing the infinite by abstracting facts or laws, relevant to experiments, from their concrete setting. If a test is to be made of the Stefan-Boltzmann law of radiation, which says that the total emitting power of any body is in direct proportion to the fourth power of its absolute temperature, the physicist abstracts from the color of the body, its shape, its atomic and nuclear peculiarities, the time of day, the season of the year, in short from all those circumstances attendant upon the experiment which do not relate to the measurement of radiation and temperature. But even after he has so abstracted subject-matter from its natural context, the physicist is not *empirically* justified on the basis of past experiment to generalize about future ones.[28] On the basis of the logic of the predicables, the reason for this reservation is quite obvious. Aquinas warns against faulty definitions, arising from the improper ordering of an attribute to the subject (e.g., as necessary or contingent when it is really the opposite) and arising from the omission of essential attributes in definition.[29] If we rely on senses alone, we are exposed to both dangers. Aquinas warns also against hasty generalization and equivocation in our search after essences.[30] Reliance on senses alone is to court these two fallacies.

In brief, the laws of physics need a firmer support than the mere enumeration of instances.[31] By the very nature of the sci-

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a series, is not wholly inductive. The mind abstracts general relations from the examples induced, and it is not necessary to carry out the calculations beyond the point where such relations can be seen. We are doing what Plato, Aristotle, and Aquinas regarded as a function—doubtless, in the case of Aquinas, the only function—of induction, providing examples for the abstracting of general truths.

The notion of infinity in mathematics is the revenge of the mathematician and the physicist for their failure to reach the unity of form and of being.

[28] Russell, B., *Problems of Philosophy*, pp. 101-102.

[29] *In II Anal. Post.* 14.

[30] *In Anal. Post.* 11.

[31] J. M. Keynes, however, points out the value of enumeration: "The object of increasing the number of instances arises out of the fact that

entific method which confines itself, to use Mill's term, to "the permanent possibilities of sensation," the physicist in his procedure cannot disengage by abstraction the essences of things which authorize necessary and universal judgments. Hence, as a physicist, employing a strictly empirical method, he cannot reach the necessary and universal. But his generalizations, tested and tried by adequate experiment, are not without their necessary and universal character. They derive it from a fact which physics cannot examine, cannot justify or deny. It is the fact of the uniformity of nature.

The question of nature's regularity cannot be settled on empirical grounds. To argue from the conclusions of experiment to their necessity is to beg the question. It is to submit to the full fury of Hume's attack on the principle of causality. It is to accept, on the basis of limited observations, a blind and ineluctable determinism pervading the whole of nature. Such a method cannot be defended on logical grounds. The indeterminism of modern physics becomes an absolute ontal fact if mere experiment is to decide the question of nature's order. Pure empiricism in the mind of the physicist must follow the path of empiricism in philosophy, to rank skepticism and the utter death of science itself.[32]

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we are nearly always aware of *some* difference between the instances, and that even where the known difference is insignificant we may suspect, especially when our knowledge of the instances is very incomplete, that there may be more. Every new instance *may* diminish the unessential resemblances between the instances and by introducing new differences increase the Negative Analogy (i.e., the diversity of cases as opposed to their similarity or Positive Analogy). For this reason, and for this reason only, new instances are valuable," *op. cit.*, p. 233. Cf. also Russell, B., *Philosophy*, p. 271.

[32] How can we speak of indeterminism in the microphysical world and determinism in the microphysical one without some standard by which we judge whether a thing is determined or not. The standard is the concept of order. On the basis of the empiricism dictated by his empirical method, the physicist could say that the subatomic world behaves in one way and the molar world in another without being able to say which is determined, or if either is determined. He could not compare the two. Comparison is necessary in judgment, and comparison is only possible when relations are seen. Relations are not formally "given" in the context of experience, as James would hold. They are known when the mind apprehends being, and being is as the bottom of every judgment. As Rousseau remarked, man and the animal differ by the little word *"is."*

Aquinas held firm and fast to an ordered nature. He held it, however, on the basis of a concept that modern scientism has rejected as anthropomorphic—the concept of final causality. *Omne agens agit propter finem.* If every agent did not act toward a determinate end, there would be no reason why one effect should follow from a given action rather than another effect.[33] But there is not only action in the world. There is interaction as well. Not only an order betweeen an individual agent and its individual effect but an order between the individuals themselves which are directed toward one end, God.[34] It is this unifying and coordinating tendency toward God (*assimilari Deo*) which builds the manifold of nature into an ordered hierarchy. Aquinas envisioned nature as the work of the Divine Artist directing all things to determinate ends.[35] Love is the tendency of beings toward their proper ends. Since God is the highest end of all created beings, they are all joined together in seeking their common goal. This tendency of all beings toward one end forms order. Hence, Aquinas says, the world is one, for all beings are ordained by an order toward one goal.[36]

Such in brief is a sketch of the order of nature as Aquinas viewed it. The tendency of things toward their ends he called the laws of nature. Law, he stated, imports direction toward an end.[37] But since scientific technique does not treat the teleological conception of the laws of nature[38] and since, from the point of view of philosophy, it is not possible to detect the intrinsic ends of physical realities of the material world except in a general sense, we are still faced with the problem of justifying the generalizations made by physics on the basis of relatively few particular instances. Scientific method rightly ignores final causality. It cannot be measured. It does not come under the viewpoint of physics, though it is a reality that must be philosophically examined if we are to have a complete account of nature. But if scientific method

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[33] *Cont. Gent.* III, 2.
[34] *Cont. Gent.* III, 17.
[35] *In Phy.* II, 14.
[36] *In de Div. Nom.* X, 1.
[37] I-II, 93, 3.
[38] Cf. Planck, M., *Physikalische Rundblicke*, p. 109.

may disregard teleology, we are still confronted with the problem of the type of necessity in the laws which physics finds in the universe. A science may disregard final causality. It cannot disregard necessity if it is to remain a science.

Aquinas argues that a natural cause, when conditions and the effect are not impeded by interference with another cause, will ineluctably produce its effect.[39] But the world of nature is an existential world. There may be the interaction of two causal series which we describe as chance. Such a deviation from nature's uniform course may be due to the material dispositions of the cause itself, to the general material conditions in which the agent acts, or to the material dispositions of the recipient of the action.[40] Matter is a principle of indetermination. Because of its surroundings in the existential world, it may be variously disposed to the form that depends for actualization on the matter's potency. Chance is the stamp of our own ignorance. It is matter subintelligible in itself and hence the source of our ignorance, that accounts ultimately for apparently fortuitous events.

Thus far, the doctrine of Aquinas on efficiency is deterministic. But it is deterministic only on the part of the cause itself as such. It is only a hypothetical determinism or necessity, presupposing the free and unimpeded implementation of the effect. But we must study Aquinas' views on this point in the whole context of his philosophical system. The determinism of the efficient cause is subordinated to the end (*primus inter causas*) of the agent. Aquinas rightly speaks of the realities which are subject to final causality as being of a conditional or consequent necessity—conditioned, that is, by end and following the order it dictates.[41]

All these principles regard not the being of nature but the activities. These are, after all, what the physicist studies. The laws of being, which involve material and formal causality, are absolutely necessary since a thing cannot be otherwise than it is. But the laws of transitive action, which involve efficiency and finality, are necessary only in a qualified sense of the word. They are in

[39] *Cont. Gent.* II, 30.
[40] Cf. note 39.
[41] *In Phy.* II, 15.

the last analysis contingent.[42] They depend on the concurrence of things outside the causes. If an effect depends on factors which are extrinsic to its causes, it cannot claim perfection from its efficient and final causes alone. There may be interference of these factors outside.

Finally, existence in the physical world is itself contingent. The material things may or may not exist. Since physics deals (and can only deal) with the existential world, its laws are always subject to the provision that agents, recipients, and the conditions of action and reception actually exist. This may or may not be the case. Even when it is not, the mere possibility of non-existence on the part of requisites for transitive action is a sign and source of contingency.[43] In the last analysis, these two sources of contingency—existentiality and materiality—are intimately intertwined. Only individuals actually exist in the physical world. They are rendered apt for existence by matter (endowed with quantity)—the principle of individuation. As Cohen says, "This uneliminable character of contingency is but the logical expression of the metaphysical fact of individuality."[44] Individual things alone can be studied by the measuring, sense-dependent technique of modern physics. The individual may or may not exist. Even when existent, it is submitted to the variable potencies of the active, receptive, and conditioning dispositions of the matter which originates it.

As Marling indicates, the doctrine of Aquinas on the order of nature thus steers a middle course between absolute determinism and utter contingency. "As long as form must consort with matter," Marling says, "as long as the universe presupposes individuals, absolute determinism is ruled out and nature's laws are stamped with a provisional character. This does not mean that scientific determinism is ruled out. It merely limits its proper sphere, as after all, science itself must be limited."[45]

But we must seek a sufficient reason for this "scientific determinism" in nature. It cannot be the issue of chance. Chance

[42] I, 82, 1.
[43] *In Phy.* II, 8.
[44] *Reason and Nature*, p. 152.
[45] *The Order of Nature in the Philosophy of St. Thomas Aquinas*, Washington, D. C., 1934, p. 119.

cannot account for the marvellous spectacle of unity in variety that strikes our eyes and amazes our inquiring minds. Even if we grant for argument's sake the indefensible premise that indeterminism, evinced by microphysics, is an objective fact, it is all the more wonderful that this apparent chaos of wave-particle units is marshalled into the ordered cosmos that forms the subject-matter of experience in life and experiment in the laboratory. Between chaos to cosmos, Plato noted, lies a gap that only intelligence can span. Nor can the activities of nature be the immediate effects of the first cause, acting on its own instruments as occasionalism holds. If God endowed material things to seek their natural ends and then stifled their native powers to fulfill their purposes, He would not be all-wise.

The regular recurrence of an effect from a given cause is then not a mark of chance, nor of God's intervention to contravene the ordinary causal sequences of nature. It is a mark of the nature of the cause itself which, not being free, acts in a necessary way. As Joyce writes, "the very concept of a natural agent devoid of free will, involves that, under the same circumstances, its action will always be of the same kind."[46]

We are forced then to the conclusion reached by Aquinas: "The same thing, remaining the same and always in the same conditions, is always bound to do the same and not contrary thing."[47] Or as he also says, the same cause will always produce the same effect, unless something external impedes it.[48] The ultimate roots of the hypothetical necessity of nature's laws go deep into the soil of traditional theodicy, for the search after the causes and reasons of a contingent world must eventually lead back to the Uncaused, Necessary Author of creation. God does not govern His world by freakish interference with the conditions necessary to effect regularly recurring sequences. "On the contrary," says Meehan, *"the conditions are present with a regularity that enables one to reach physical certitude and the presumption that the same order which has been observed in the past will continue in the future is reasonably based upon man's knowledge of both the wisdom and immutability of God, who ordains all things suaviter and firmiter and without caprice."*[49] There is an order in nature based on final causes. But since matter may prove freakish, we must, in speaking about that order, carefully qualify "necessity" with "hypothetical" —hypothetical, that is, in the sense that the order depends on the concurrence of the material conditions outside the final and efficient causes combining to produce an effect.

[46] Joyce, G. H., *Principles of Logic*, London, 1926, p. 237.
[47] *In II de Generatione et Corruptione*, 10.
[48] *In Phy.* II, 14.

It was pointed out above that induction by simple enumeration could not guarantee the distributed middle term which is necessary for demonstration. Every simple enumeration, unless it is complete, suffers from an undistributed middle term; when complete, if we have any means of determining that we have a complete enumeration, it is then a mere vicious circle because the individual case is already known before being "deduced" from the collection. Now the order of nature enables us to overcome both of these difficulties. By the principle of uniformity, we can generalize from the limited range of actual experiments to all possible cases of the phenomena in question. We can then truly make the conversion in the minor premise which, we saw, was proposed by Aristotle to overcome the undistributed middle term. We can also draw conclusions concerning possible experience without becoming involved in the diallela of actually postulating the knowledge of the individual which must be already *formally* included in the premises before we can deduce it as a conclusion. Francis Bacon rightly criticized simple enumeration. But physicists must adopt it, with all of its errors and all of its weaknesses, unless we go beyond the empirical method to a discussion of the non-empirical realities upon which alone genuine physical science can take firm root and be truly scientific.

Scientific laws are only hypothetically necessary. Under the same conditions and in the same circumstances, the same effect will follow the same cause. But our generalizations must be qualified by the fact that since we are dealing with the existential world of material individuals the effect may be impeded. Hume was right in holding that succession cannot guarantee necessity in itself. But there is more than succession in the philosophical analysis of

[49] *Efficient Causality in Aristotle and St. Thomas*, Washington, D. C., 1940, p. 393.

nature's regularity. Ampere's law, Moseley's equation, and the gravitational tensors of the relativity theory will be obeyed whenever the necessary conditions are realized. We know this, not by a merely empirical conclusion based on observed succession in the past, but from an intellectual analysis of the order of nature. Hence we must step beyond the boundaries of physics, if we are to reach a complete and rational account of nature, into a study of the primary substrate and actualizing substance of matter; more importantly must we study efficiency and finality which are the fundamental determinants of nature's activity. Closed off from the world of essences which alone authorize necessary predication, physics nonetheless seeks admission to that world of necessity by a circuitous route. But physics is thwarted in its attempt.[50] It works on a level where the realm of essences is not attainable. So long as this is the case, it is subject to only a provisional necessity no matter how numerous its verifications may have been in the past. So long as it works with individuals which are the antithesis of the universal notes necessary for demonstration, its conclusions are contingent upon the interference, in causal sequences, which makes for deviations. Enumeration, based on inductive division, is, even when supported by a knowledge of nature's uniform course, not sufficient for absolute necessity. Only the abstracting of the specific types or the transcendental notes, contracted in material individuals, can yield the true universal which is such *ut non oporteat ulterius medium quaerere.*

Statistics and indeterminism which express conclusions of physics in the exact language of mathematics do not correct for the contingency of nature's laws. If chance in an otherwise ordered nature is the mark of our *negative* ignorance, probability is the mark of the same fact in a privative sense. In the problems where, in the language of physics, determinism prevails, we have traced the normal curve of nature's behavior which, however, is still subject to contingent circumstances and conditions. Our formulation of causal sequences may be stated in exact mathematics but the sequences will be submitted, when we generalize them into laws, to the sometimes retractable behavior of contingent matter. In

[50] Cf. Thompson, W., *op. cit.*, p. 32.

the case of statistics and of indeterminism, we have not been able to unmask the hidden laws which govern nature, either because the task is empirically impractical or because of the computational difficulties involved. We have introduced a new variable. The laws of probability in statistics or in quantum-mechanical probability-amplitudes, far from correcting for the contingency of the laws of nature have, in reality, added a second—and purely subjective—element of contingency to the objective fact that the activities of nature are contingent on the free and unfettered exercise of efficient causality. The fact that over large aggregates, probability approaches certainty (or in the language of mathematics a 1/1 ratio) and that when we make certain assumptions, as in classical or quantum statistics, correspondingly exact conclusions can be deduced[51]—all this is proof, if proof is needed on this basis, that nature follows a regular course when left to itself and is not a toy of sheer chance, behaving, as the popularizers sometimes say, as though atoms have free will.

The fantastic conclusions drawn from the statistical treatment of the second law of thermodynamics, that water may sometimes freeze on a fire or that a stone may fall upward, are results of the fact that mathematics is the only language which physics knows and that physicists have made it into a universal logic, beyond the expressions of which there can be no legitimate knowledge. They say, to take a rather obvious case, that according to the Bohr correspondence principle quantum mechanics approaches classical mechanics *asymptotically* when particles become numerous and the energy of a system becomes high. But an *asymptote* is a mathematical concept, not a physical one, and to apply it, as it is in mathematics, to physical reality is to follow in the footsteps of Zeno. Macrophysical events in ordinary space obey Newtonian mechanics, as experience attests, and they obey it now as unerringly as similar events observed in the nineteenth century. Physicists have simply discovered in the twentieth century new facts on a different level. They have not denied the *facts,* as facts, discovered by Newtonian physicists and generalized into scientific laws. Such facts are still recognized and treated, classically, by the

[51] Cf. *supra,* p. 47.

contemporary physicist who usually forgets in practice about his asymptote. The human intellect by an abstractive analysis validates this Newtonian treatment of the order expressed in Newtonian physics (as far as this is empirical and factual, i.e., a law in the strict sense). The abstractive analysis is in the light of nature's order. Physicists may claim that Newtonian mechanics is only asymptotically true—because they consider quantum mechanics to be fundamental. But this statement in actual practice becomes purely verbal. It is only theoretically stated because physicists will not accept intellectual analysis which finds a universal order in nature. Such physicists prefer mathematical terminology, although it is scarcely intelligible in this case, even for stating nature's most universal regularities. They do so because mathematics is the only intellectual discipline that they understand in their laboratories and that they recognize when, like Eddington, Jeans, Bridgman, and a host of others, they venture into philosophy.

The same substitution of measurement and of mathematics for abstractive insight and for traditional logic is responsible for the grotesque statements based on thermo dynamics. In modern physics, with its technical, mathematical concepts like that of an *asymptote, limit, infinitesimal,* and mathematical *infinity,* we confine ourselves, if we are treating thermodynamics statistically, to a relatively small distribution and the strictly *mathematical* technique involved in computing the final distribution, from the initial one. In such a case, we may, as far and only in as far as we are dealing with the problem from a rigidly mathematical viewpoint, draw the apparently extreme conclusions that a heated kettle will freeze or that a stone will fall up. If we begin with a probability ratio in mathematics, then we can never end in a one-to-one ratio, even if the original distribution be overwhelmingly in favor of one alternative and if the limits of integration are increased a million-fold or more. This purely mathematical side of the picture motivates the fantastic statements on future probabilities. Observation supplies data for an initial distribution; for reasons already stated we may not be able to measure the individual sample in a precise way, so we have probability equations. The equations are mathematically developed. They are enunciated in general form as though the course of nature could be forecast from the purely

mathematical development of observations in microphysics. Mathematics is the only language which physics speaks. Since a probability ratio in the beginning can, quite naturally, never yield a one-to-one ratio in the end which is what the scientist calls certitude, physicists who adhere to mathematics alone in all their organized thinking, believe that all events must be described in terms of the increasing "disorder" noted in statistical thermodynamics.

But the physical order is not synonymous with the mathematical order. In the universe, there are not only numbers. There are natures. The "disorder" is, like chance, the seal of man's ignorance. If the material entities which seem to be in chaotic movement, obediently to the law of entropy, have no final cause ordaining them to definite ends, there would be no sufficient reason for their action. Such entities could neither act nor exist. They would be contradictory. The "disorder" is a sign of our mind's debility. Being presupposes order. A disordered movement is necessarily repugnant; for if every material being did not have a definite and determined tendency, a definite goal, it would tend in all directions, and no movement would be possible at all. To depart from relatively few observed data in microphysics and then treat them by *mathematical* formulae, as though mathematics could give a complete account of all the activities of nature, is not a logical procedure. True, we could never reach mathematically the 1/1 ratio if we start out with probabilities. But enumeration here is only satisfactory in mathematics as such, and the conclusions cannot be applied to the physical world as such with the pretense that there are no other factors active in nature except the mathematical. If we so apply them, we must bear in mind two points: first, that we are assuming that there is nothing which determines the world of visible experience except the mechanical activities of the microphysical order; and secondly, that we are assuming mathematics to be the complete—and indeed the one and only—reasoned discipline that we apply to the study of matter.

The first assumption explains away the world of quality or form. The second explains away finality or order. But order in nature is not resolvable into mathematics. It can only be studied in its ultimate basis by the intellectual insight, into nature, of the method of philosophy. It is abstraction that bridges the gap, which enumeration can never get over, between the probability ratios revealed by statistical thermodynamics and the different type of order which is an observed fact in visible experience. All beings act toward definite and determinate goals. To say that a heated kettle of water will freeze or that a stone may fall upward is to overlook finality and make it non-existent simply because it is not amenable to treatment by mathematics. It is to hold that physical observation is the only form of direct *apprehension;* that measurement alone is a meaningful *judgment;* and that mathematical operations are the be-all and end-all of all *discursive* knowledge. It is to deny the validity of abstraction which can proceed above and apart from the probability ratio of an initial distribution of samples that yields mathematically a corresponding probability ratio in the final distribution. In so proceeding, abstraction can analyze material things in the clear light of nature's order, thereby attaining to hypothetical necessity. If we stick to mathematics alone, the physicist is justified in his sometimes weird predictions. But mathematics as the whole story of nature's behavior will never do. *Omne agens agit propter finem.* Final causality may lie beyond the compass of physics and mathematics; but this is a sign of their incompleteness, not a sign of the unreality of final causes. Finally, it may be repeated that probability in the vocabulary of the physicist is not equivalent to *hypothetical necessity* in the vocabulary of traditional philosophy. The former is a sign of our privative ignorance; the latter of our negative ignorance. Deviations from the hypothetical necessity cannot be mathematically forecast; they may affect the exact ratios predicted by the statistical physicist or the probability amplitudes forecast by the Schroedinger equation. In the case of hypothetical necessity we have an objective deficiency, deviations from the normal course of nature. In the cases of statistical mechanics and quantum theory, we have a subjective deficiency, because we are ignorant of nature's normal course in cases of individual phenomena.

Relativity has purported to correct for the errors in measurement made by classical mechanics. Whether it succeeds in doing this is a question for physics, not for philosophy. But here too, the transformations of the restricted theory and the tensor equations of the general theory are subject to the contingent character of the

material individuals with which they work. If relativity has improved our measurements of matter, it has not changed matter's ontological status and the consequent contingent character of matter's activity. This contingent character is independent of our logic of measurement, whether it be implemented according to classical, quantum, or relativity mechanics. It is imbedded in matter itself, however it is studied.

On the basis of the hypothetical necessity of the laws of physics and the necessary laws of metaphysics, we can distinguish two kinds of certitude. The former is the firm determination of the intellect to one member of a pair of contradictories because nature, except in very rare and unforeseeable cases, follows a normal course; metaphysical certitude, which holds in metaphysics and mathematics (as pure mathematics), includes no fear of error whatsoever. It is based upon an abstractive knowledge of essences which cannot be otherwise than they are. But physical certitude is not mere probability. It is based upon the order of nature, upon the "scientific determinism" which rules the world of matter—a world where each being tends ineluctably toward a preordained end and where regularity is guaranteed by Divine Wisdom itself. Practically, this state of mind is one of certitude. If the caprices of chance ruled the world and if the only law, to borrow from Rousseau, were that there is no law, God would contradict His Own Intelligence (*sapientis est ordinare*). Moreover, in the universe itself, even the actually observed order in which past predictions have proved reliable would lack a sufficient reason. Lacking this, they would be contradictory.

There is a tendency among modern physicists to reduce all laws to probability and statistics. There is a similar current among modern logicians and such widely different thinkers as Russell and John Maynard Keynes. Keynes writes that "it is generally agreed that an inductive conclusion is only probable, and that its probability increases with the number of instances upon which it is founded."[52] But this statement is very misleading. Statistics is only a logical substitute for an expression of law in individual cases where the law is baffling; it is not an ontal fact which replaces law in individual cases because such a law does not exist.

[52] *Op. cit.*, p. 107.

An induction need not be mathematical. The statement that "an inductive conclusion is only probable" can be met with the answer that both induction and probability may be equivocal. The hypothetical necessity of nature's order is not a mere mathematical probability, as Keynes' doctrine seems to suggest; it is rooted in matter as an *ontal* fact and so is not amenable to *mathematical* treatment. Hence this induction to hypothetical necessity is a logical and not mathematical process, though mathematics may sometimes help to suggest the logical generalization.

Mathematics cannot probe down into the nature of matter where contingency is rooted. It can only predict probabilities when a distribution, and therefore order, is known in advance. In the last analysis then, probability calculations, in the domain where they can be empirically verified, are based not upon the contingency but upon the order of nature. Successful statistical theory must be based on a frequency value. Probability calculus, while expressing conclusions in the language of "contingency" with respect to individual cases, presupposes an ordered distribution. It is a fallacy of the most fundamental and far-reaching importance to our whole reasoned outlook on the universe to confuse the genuine notion of contingency in nature (negative ignorance) and the probability calculations (privative ignorance) of modern physics. The notion of probability in statistics and in quantum mechanics is not based on finality, since the concept of end is rightfully ignored in modern physics as physics and has no place in mathematics; it does not explain chance, since probability calculations in a solution presuppose an initial order from which they were derived; it does not take account of divine intervention which may contravene observed order by impeding the production of effects, as in miracles. The traditional notion of contingency takes account of all three of these factors which are outside the ambit of mathematical physics and which can as much affect the ordered distribution of statistically treated realities or as much affect the probability-amplitudes of the Schroedinger equation as they can contravene the ordinary, non-statistical laws of macroscopic Newtonian physics.

Traditional principles of logic can also be used for a realistic assessment of the method of hypothesis in physics. Knowledge, for instance, must proceed from the known to the unknown. Consequent knowledge must be based on prior knowledge. And the principles must be better known than the conclusions we draw from them.[53] It requires only a cursory glance at modern physics to show that in the method of hypothesis this proper procedure of knowledge, from known to unknown, from premise to conclusion, from more familiar to less familiar, is not observed. Indeed, the opposite seems to hold. A hypothesis is, as we say, a supposed cause. The facts suggest theories. But since a theory is verified by its predictions, the facts are used chiefly to test theories by. A hypothesis is then a leap into the unknown. This fact is apparent from the very suppositional nature of a theory.

The hypothecating type of reasoning employed in modern physics bears analogy to the scholastic causal demonstration, as was already said. This is only an analogy, a hypothesis is not a definition. In the last analysis, it is only an "educated" guess. It is not altogether an *in*duction in the sense of an abstraction. It is, in Comte's language, a *pro*duction of the speculating human mind, i.e., an art. Definition corresponds with the facts that give it birth; a hypothesis, we saw, merely coheres with them. Genuine philosophy may submit that hypotheses be judged by the coherence doctrine of truth. The difference between the coherence and correspondence doctrines of truth is precisely the difference between procession from the unknown to known and the reverse.

A theory may be viewed from two viewpoints which are at least logically distinct: a) theories as interpreting (predicting) phenomena; and b) theories as verified or validated by the phenomena. Under the first aspect, a theory is a mental construct whose middle term of causal demonstration where the cause, it was seen, is hypothetical, expressing content; it is not the existent essence of strict demonstration. Under the second aspect it must be judged in the light of the principle that by some other theory yet unknown to men the appearances may be saved.

On traditional principles, it may also be asked whether our way of proving hypotheses does not involve an illicit process of the major term. Aquinas and Aristotle point out that appearances may be confused with the essences of things. Thunder, it is said by way of example, is referred to as being a noise in the clouds; but this

[53] For a statement of these three principles, cf. *In I Anal. Post.* 3, 6, 5.