

THE LIMITS OF A LIMITLESS SCIENCE

STANLEY L. JAKI

The title of this essay is paradoxical and intentionally so. It aims, as do all paradoxes, at alerting the mind to something that should be obvious, but is not necessarily so. For little attention is paid to the obvious fact that whatever one's idea about science, it does not reflect a consensus about it. In fact there are almost as many ideas about science as there are philosophers of science. But there is at least one aspect or feature of science which must be included in all ideas about it. Indeed, as will be seen, that feature guarantees a limitless application of science or of the scientific method, and, at the same time, constitutes its most tangible limit. The feature relates to the fact that for a proposition or reasoning to qualify as science, it must be subject to being tested in the laboratory, or, in general, by scientific instruments.

This does not mean that a reasoning which cannot be tested in the laboratory is unreasonable. It is not possible to dispute, without waxing philosophical, that philosophy is not a reasoned discourse. Theology, as cultivated within Christian circles, was long ago proposed as a science by no less intellects than Augustine and Thomas. But they and an army of lesser though still eminent intellects called philosophy and theology a science only because they saw in it a discourse consistent with its basic premises and presuppositions. It is in that sense that they took philosophy and theology for *scientia*. One wonders whether they would insist on that name nowadays when the word *science* has a very special meaning attached to it. That special meaning is tied to the word laboratory and the kind of work done there.

For although the word "laboratory" may, etymologically, mean any place where one "labors," it actually denotes a place where one works for one single purpose: to make observations or measurements which are accurate, so that accurate predic-

Stanley L. Jaki, a Hungarian-born Benedictine priest, is Distinguished University Professor at Seton Hall University. Winner of the Templeton Prize for 1987, he is an honorary member of the Pontifical Academy of Sciences. His fortieth book, Means to Message: A Treatise on Truth, has just been published by Wm. B. Eerdmans.

THE ASBURY THEOLOGICAL JOURNAL

SPRING 1999 • VOL. 54 • NO. 1

tions may be made on their basis. Science, in that sense, is synonymous with measurements, which are accurate because they can be expressed in numbers. Those numbers relate to tangible or material things, or rather to their spatial extensions or correlations with one another in a given moment or as time goes on. All the instruments that cram laboratories serve the accurate gathering of those numbers, or quantitative data.

This is most evident with respect to physics, the most exact form of what in modern times is called science. Any branch of physics is an example of this. There is a science of dynamics because something about what is perceived as attraction among bodies can be measured. There is a science of acoustics because the intensity and speed of sound are measurable. There is a science of optics because a great many things can be measured about light rays, such as the diminution of their intensity with distance, and their ways of propagation. There is a science of electricity, because one can measure the magnitude of electric charges and the forces of attraction and repulsion among them. There is a science of electromagnetism because it is possible to measure the interaction of electrical and magnetic forces that generate electromagnetic waves. These in turn have velocity, amplitudes, frequencies, and a number of other parameters that can be measured. There is atomic and nuclear physics because atoms and their nuclei have measurable properties. Astronomy is a science because the size of stars, their distances from one another, and the processes within them can be so many objects of measurement.

Outside physics, all branches of science have tried to emulate physics by restricting their work as much as possible to measuring. In that respect chemistry has achieved a status of exactness practically equivalent to that of physics. Great advances have been made toward exactness in biology ever since Harvey made measurements that revealed the circulation of the blood through the body. Every page of modern molecular biology and biophysics attests to the overriding importance of measurements.

In very recent times psychologists, historians, sociologists, and economists claimed for their studies a scientific status. One speaks today even of political science, or the science of politics. The reason is that in all those fields a great deal of systematic data gathering can take place on the basis of which much can be said about future developments either in individuals or in society. But whenever perfect accuracy is claimed for such predictions, the free character of individuals and of society, together with the freedom of scientific research, is called, at least implicitly, into doubt. At any rate, the gathering of data and measurements in those fields never achieved a predictive accuracy which is on hand in physics, astronomy, and chemistry. In all these fields, science is practically synonymous with the very special work done in laboratories. The work is to take measurements.

Physicists have expressed in various forms their awareness of the importance which measurements have in their efforts. In doing so they have also voiced crucial points about what is involved in making measurements. One such point is the scientific status that can be given to a branch of investigation insofar as it includes measurements. In fact, some physicists spoke as if knowledge not based on measurements was mere "hot air," to recall Lord Rutherford's aside to Samuel Alexander, a well-known metaphysician.¹ At other times they merely hinted at the lower status of non-scientific knowledge. Such was the case when Lord Kelvin, in discussing in 1883 the electrical units of measurement, recalled a favorite comment of his on what constitutes science: "I often say that when you can

measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unscientific kind: it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be.⁷²

There is no point in speculating to what extent Lord Kelvin wanted to slight thereby other sciences and non-scientific branches of knowledge. Even in physics it was true that a branch of it, or any theory indeed, increased in scientific value in the measure in which it involved measurements, that is, numerical values. The most concise expression of that view is due to Robert Mayer, one of those who put the mechanical theory of heat on a firm footing. His dictum, "In physics numbers are everything, in physiology they are a little, in metaphysics, they are nothing,"⁷³ also states a parameter along which various branches of learning can be seen as qualifying in various degrees as science.

Mayer, a physician by training and profession, would, of course, find himself contradicted today by the role of numbers, that is, exact measurements, in physiology. His remark on metaphysics could be justified only insofar as numbers were taken to be equivalent to making measurements. Obviously, ideas cannot be measured by calipers or dissected by microtome. However, insofar as numbers represented the metaphysical category of quantities, Mayer should have known that the best metaphysicians have always viewed the category of quantities as being above all other categories. More of this later. Still, Mayer was correct in saying that in physics numbers were everything. In reference to physics he was fully justified in declaring: "One single number has more real and permanent value than an expensive library full of hypotheses."⁷⁴ He had in mind his many years of labor to establish as precisely as possible, and in most varied circumstances, the mechanical equivalent of heat.

To that kind of labor, done in laboratories, physicists have often assigned the status of judiciary tribunal for science. Einstein had in mind certain numerical values implied in his general theory of relativity when he said in 1919 that "if a single one of the conclusions drawn from it proves wrong, it must be given up; to modify it without destroying the whole structure, seems to be impossible."⁷⁵ The experimental evidence that the separation of the components of the fine structure "doublet" in H_{α} is only 96 percent of that predicted by Dirac's relativistic quantum theory, forced the working out of quantum electrodynamics. Many other examples are provided by classical and modern physics about the supreme role played by measurements.

No wonder that physicists could speak of their being devoted to measuring things and processes as if it had been an obsession with them. A. Kundt, a physicist famous for his measurements of the velocity of sound in gases and solids, once stated that "in the end one might just as well measure the velocity of rainwater in the gutter." What he meant, of course, was not a commitment to measuring for the sake of measuring, a sort of scientific *l'art pour l'art*. He meant the establishment of a numerical figure that forms part of a meaningful scientific theory. It was in that sense that F. Kohlrausch, a physicist also famous for his painstaking as well as decisive measurements, found Kundt's suggestion congenial to his own way of thinking: "I would be delighted to do so"⁷⁶—was his comment.

Science is competent wherever and whenever the object of investigation offers a quan-

tatively determinable aspect. The range of science is not limited either by the dimensions of quarks or by the distance to the farthest galaxies. Science touches on all matter—whether solid, liquid, gas, plasma, or a mere flow of energy waves—insofar as matter is extended and therefore measurable. Consequently, science is applicable wherever there is matter in any form whatsoever, because all such matter has quantitative parameters. In that sense science is limitless and its statements are unlimitedly, that is, universally valid throughout the universe of matter.

It is another point that the total amount of matter, which is measurable, has to be finite. An infinite amount of measurable matter would be the embodiment of an actually realized infinite quantity which is, of course, a contradiction in terms. Again, it is another matter that the quantitative ascertaining by science of the quantitative structure of matter can never have an end to it. A physical theory can never be final for two reasons. For one, physicists can never be sure that they will never stumble on some previously unsuspected features of matter. Also, even if they were to succeed in formulating a “final” theory, they can never be sure theoretically whether it is really final. For as long as Gödel’s incompleteness theorems are valid, the mathematical structure of that theory cannot contain within itself its own proof of consistency.⁷

Science, insofar as it deals with quantities, is not limited by non-quantitative considerations. No non-quantitative set of considerations, be they metaphysical, theological, or aesthetic, can set a limit to the competency of science. But this limitless character, which science enjoys with respect to the quantitative aspects of reality, is also the source of its drastic limitedness. This is clear even within that most quantitative of all sciences which is physics. Thus to take only one branch of physics, electromagnetism, its scientific status rests on the fact that electromagnetic waves have measurable properties. Perplexities envelop that status no sooner than one yields to logic by saying that if there are waves, electromagnetic or other, there has to be something which performs that wave-like motion. For if that something is called electricity, an answer is given that appears satisfactory until one asks: what is electricity?

An answer to that question evades the physicist. This was admitted even by Lord Kelvin, who stuck to the end to his conviction that ultimately every physical process and property had to be mechanical. Yet this was not what he said to a young foreman in a big Glasgow electrical equipment factory, who happened to guide through the plant the great physicist, without recognizing who he was. After Lord Kelvin listened with great patience to elementary instructions about condensers, insulators, magnets, and whatnot, he decided to give a gentle lesson to the all-knowing young man, by asking him: “What is electricity?” On finding, not surprisingly, that the young man was at a loss for words, Lord Kelvin gently assured him: “This is the only thing about electricity which you and I do not know.”⁸

Physicists are, of course, apt to answer that electricity is a field, like gravitation. But then another question can be raised: What is a field? If we answer that a field is an oscillation, the answer begs the question: what is it that oscillates? A particular difficulty arises if one goes on to quantum electrodynamics with its fields of zero-point oscillations in the vacuum. Can such a vacuum be really empty, as it should if it is truly a vacuum?

The quantum-mechanical vacuum and its no less baffling conceptual affiliates are but the latest in the long list of such questions. Already in Newton’s time it was realized that

physics cannot answer the question: what is gravitation? Physics could only establish the fact that what is called gravitation has a quantitative property, known as the inverse square law. Almost two hundred years later, when Maxwell worked out his electromagnetic equations, much effort was spent, but in vain, on finding out what it was that acted according to those equations. The most popular theory, indeed conviction, was that the something in question was the ether, but physicists could not measure anything about it. They could not even measure a presumed effect of it on the speed of light beams sent through it.

This famous null-result of Michelson's experiments forced physicists to declare the ether to be non-existent. Indeed this conclusion of theirs was valid insofar as the ether was thought of as something material and therefore an entity with measurable properties. Even today, after all the successes of quantum electrodynamics, physicists cannot improve on Heinrich Hertz, the first to demonstrate effects predicted by Maxwell's theory, effects naturally interpreted as produced by electromagnetic waves. In an almost despairing tone Hertz wrote: "Maxwell's theory is Maxwell's system of equations."⁹ Such is a concise expression of the radical limits put on science to say anything about the so called electromagnetic medium, be it called field or vacuum or whatnot.

Maxwell's equations, like all other equations of physics, are a set of quantitative correlations. Nothing more, nothing less. And the same can be said of the tensor equations of the general theory of relativity and of the matrices and wave equations of quantum mechanics. In other words, if Hertz's remark is right, one can say that Einstein's general theory of relativity is Einstein's system of equations, or a set of generalized quantitative correlations. Indeed, one may say that all theories of physics are generalized sets of quantitative correlations.

This conclusion sets very sharp limits to the applicability of science: wherever reality offers aspects with no quantitative properties to be measured, science is not applicable. In addition, as will be seen, the scientific specification of those quantitative properties cannot be taken for an initial installment on specifying non-quantitative properties of the same reality. Quantities forever remain quantities, conceptually that is. This is, however, not something to trouble scientists insofar as they assume, on the basis of common sense wisdom, that there are things and processes to measure and they are satisfied with measuring some features inherent in all things. But the same restriction of the applicability of science keeps troubling some scientists. These, being overawed by the success of the quantitative method, think that science should be applicable in every field of human experience and reflection.

This conviction of theirs can manifest itself in an almost incidental, yet very startling manner. A good example of this can be found in a chapter which deals with "The Flow of Dry Water," that is, non-viscous flow, in the *Feynman Lectures*, a highly regarded textbook on physics. There Feynman makes two final remarks. One is that from the relatively simple principles governing non-viscous flow an "infinite variety and novelty of physical phenomena . . . can be generated; . . . we just haven't found the way to get them out."¹⁰ This may be taken merely for an ambitious program for physics, provided one does not take the words, "physical phenomena . . . can be generated" for an endorsement of some ill-digested form of Platonism where numbers produce physical reality.

But a worse perspective, that has nothing to do with physics, transpires from

Feynman's next remark in which he bemoans the fact that "today we cannot see whether Schrödinger's equation contains frogs, musical composers, or morality—or whether it does not."¹¹ Feynman does not say categorically that it does. Yet by taking as plausible the possibility that Schrödinger's equation may contain all that, Feynman claims that science is limitless in a sense very different from the one already stated, namely, that science is applicable wherever there are quantitative properties to measure. This unlimitedness of science is extended by Feynman into a sweeping suggestion with no restriction whatsoever: Not only matter but everything else, morality included, can be measured, and indeed is contained in some future form of physics.

What Feynman put forward in an almost incidental way, other prominent physicists present in a systematic manner. An example is Roger Penrose's book, *The Emperor's New Mind*. There he argues that some new, and so far unknown form of general relativity, which is quantized and therefore statistical, will contain the full explanation of all human thought. There is much more to Penrose's idea than the far from demonstrated claim that thoughts can be measured. What Penrose really claimed was the old Platonic idea that ideas of quantities necessarily turn into real matter with quantitative properties. Therefore, since mathematical physics is the best way of dealing with the quantitative properties of matter, mathematical physics is declared to be all that we need in order to cope with existence, material as well as intellectual and moral.¹²

A variation on this claim is found in Stephen Hawking's book, *The First Three Minutes*. According to its grand conclusion, a theoretical cosmology, which is so perfect as to be free of boundary conditions, automatically assures the existence of the universe.¹³ Another prominent physicist, A.H. Guth of MIT, relies even more crudely on this rather naive cavorting, in the name of physics, with Platonism. According to him quantum cosmology gives the scientist the power to create universes "literally" and "absolutely out of nothing."¹⁴ If, however, physics turns the physicist into a Creator, there remains absolutely no limit to science.

Now, if such scientifically coated claims are true, one might as well follow the advice which David Hume gave at the end of his *Enquiry Concerning Human Understanding* and burn all books except those that contain quantities and matters of fact.¹⁵ Obviously, Hume meant only those facts that were material and therefore could be measured or evaluated in terms of quantities. At any rate, ever since Hume the book burning recommended by him has been busily done, at least in a metaphorical sense. It is, however, well known that during the French Revolution and kindred ideologico-political revolutions, pyres were made of books that lacked quantities and matters of fact as understood by Hume. Metaphorically, that book burning can be done (and this is the way it is done in the name of science), by declaring that anything that cannot be measured is purely subjective, almost illusory. Einstein himself claimed that since our experiencing the "now," which is the very center of human consciousness, cannot be measured, it is a purely subjective matter.¹⁶ He said the same thing about free will as well.¹⁷

But then should a scientist accept a prize, say the Nobel Prize, for his work if he was not really free when he worked for his discoveries? Are we to reward sheer automata with huge and prestigious awards? But how would this be a non-automatic process? In order to have a proper answer, one should first recall the penetrating observation of a sci-

entist, Henry Poincaré, who, about a hundred years ago, called attention to an elementary fact: "Even a determinist argues non-deterministically."¹⁸ Clearly, both within and outside science, the claim that science has no limits would, if rigorously applied, lead to absurd consequences.

Nothing would remain of the criminal justice system, if a criminal could claim, with a reference to Einstein, that his consciousness of having committed this or that crime was purely subjective. Should criminal justice courts admit purely subjective evidence and impose, on that basis, huge prison terms? If free will is purely subjective, what becomes of arguments, either scientific or philosophical, against free will? Those arguments then cannot be submitted as having objective validity. But an argument which is not the result of free deliberations, is not an argument. If, however, those arguments against the freedom of the will are not purely and blindly mechanistic processes, they are so many proofs of the existence of free will.

Such consequences are at times blissfully ignored by prominent scientists. Worse, they fail to notice that even in their own scientific field mere measurements and quantities do not suffice. A telling illustration of this comes from the Einstein memorial lecture which Professor Watson, the co-discoverer of the double helix structure of DNA molecules, gave at Princeton University on February 16, 1995. There he amplified his statement that all human life can be described in terms of molecules, with the words: "There is no need to invent anything else."¹⁹

Should one then say that life as such does not matter, because it cannot be observed or measured, in spite of the enormous successes of biochemistry, biophysics, microbiology, and genetic research? They certainly show the enormous extent of measurable parameters in life processes. But life itself still cannot be measured. Therefore, scientifically speaking, life does not exist. This paradoxical fact was in the mind of Claude Bernard, the great French physiologist, when he made, around 1860, one of his famous statements. On being asked whether, in reference to life, he was a vitalist or a mechanist, he replied that he had never seen life.²⁰ This was his way of calling attention to the fact that by becoming either a vitalist or a mechanist, one moved beyond science. There remains, indeed, much more to the question, "What is Life?" than can be dreamt of by biochemists or biophysicists who take the mechanistic outlook on life. Equally, biologists who espouse vitalism are dreaming when they imply that they can see experimentally purposiveness, this chief characteristic of life processes. Just as the mechanistic interpretation of life is a philosophy, so is vitalism. Both are bad philosophies, though in an opposite sense. In the former the claim is made that just because something (purposiveness) cannot be measured, it does not exist. In vitalism the claim is made that somehow purposiveness can be measured and therefore becomes part of experimental science.

Contrary to the claim that DNA is the secret of life, life remains the secret of DNA. Microbiology has not found a quantitative answer to the apparently purposeful action in all living things, from cells to mammals. Microbiology has not found a quantitative answer to the question of free will. Brain research cannot answer the question, "What is that experience, called 'now,' which is at the very center of consciousness?" For even by finding the exact biochemical conditions that are connected with the personally felt consciousness of the "now," the question what is that "now" remains to be answered. While

brain research may establish the biochemical processes whenever a given word is thought of, it cannot account for what it is for a word to have a meaning.²¹

Faced with that inability, the scientist can take two attitudes. One rests upon the mistaken conviction that the scientific method is everything and whatever cannot be expressed in quantitative terms, is purely subjective, that is, illusory. Such was, as noted already, the attitude of Einstein, who claimed that consciousness and free will are not objective realities, because they cannot be handled by physics. He might as well have called them sheer illusions. Clearly, it is better to take another attitude and acknowledge that there are some basic limits to a limitless science. Those limits appear as soon as a question arises that cannot be put in a quantitative form and therefore cannot be given a quantitative answer to be tested in a laboratory.

Such are indeed all the major questions of human existence. To answer the question, "To be or not to be?" we cannot turn to a science textbook. Strictly speaking, for Hamlet the question meant a choice between two courses of action: one was to continue to live by ignoring an immoral situation. The other was to take revenge and run thereby the risk that one's physical being would come to an end. Already that moral choice demands far more than some quantitative testing in a laboratory.

But Hamlet's question, "to be or not to be," has a meaning even deeper than whether an act is moral or immoral. That deeper meaning is not merely whether there is a life after death. The deepest perspective opened up by that question is reflection on existence in general. In raising the question, "to be or not to be," one conveys one's ability to ponder existence itself. In fact every bit of knowledge begins with the registering of something that exists. To know is to register existence. But this is precisely what science cannot do, simply because existence as such cannot be measured. Yet, worse than impotency is on hand in thinking about existence when it is done in terms of a philosophy that apes scientific parlance. A philosopher, no matter how eminent, makes a mockery of his field when he keeps asserting that "To be . . . is to be the value of a variable."²² Compared with this, it may strike one as an innocent joke to say, as did a graduate student of physics, that Hamlet was an internal combustion engine, with a very low efficiency, because he could have prevented the death of six people by simply killing one, his mother.²³

When science establishes, for instance, the quantitative knowledge that the earth's diameter is so many kilometers, it presupposes first of all the fact that something, the earth, does exist. And this holds true of any quantitative result of science, such as atomic radii, distances to other galaxies, the characteristic wavelength of the cosmic background radiation, etc. Atoms and galaxies are useful objects for science because they exist in such a way as to have quantitative properties. Moreover, science can, by refining more and more its measurements of those properties, establish such sets of them that are conveniently called new subatomic entities.

But it would be mistaken to assume, although this is customarily done, that science, or rather its quantitative method, finds new entities in the ontological sense. Science merely uncovers new aspects in the vast gamut of material existence. Were it otherwise, one would endorse the Platonic fallacy that it is the quantitative properties that give existence to material entities. Moreover, were such the case, nothing would exist that cannot be given a quantitative formulation. In that case such words as conscience, free will, purpose,

moral responsibility, to say nothing of the soul, would be so many empty words, standing for anthropomorphic illusions. But, there would not be, in that case, even scientific investigations, because there would be no scientists who would investigate things freely and be conscious of the fact that they are investigating.

In other words, there is a most fundamental limit to a limitless science. Science has no limits whenever it finds—and in whatever form—matter or material properties. There is no limit, for instance, to measuring the physiological processes that take place in the brain when one thinks as much as a single word. It is possible that one day brain research will be so advanced and exact as to give a complete quantitative account of all the energy levels of all the molecules in the brain when one makes the conscious reflection on the “now.” But even then there remains the radically non-quantitative character of that experience, a character clearly recognized by Einstein. He merely failed to recognize the limits of science when he stated that whatever cannot be measured and therefore be expressed in quantitative terms, cannot be objectively real.

Einstein failed in this respect, as did and do so many other prominent scientists. He failed a test to which his great idol, James Clerk Maxwell, gave the best formulation. Towards the end of his most distinguished career, Maxwell put in print the following words: “One of the severest tests of the scientific mind is to know the limits of the legitimate application of the scientific method.”²⁴ That method can be legitimately applied wherever one can find experimentally verifiable quantities.

The expression, “experimentally verifiable quantities,” is crucial. Theology too deals with quantities. Theology states that there is one divine nature in three divine persons; that in Christ two natures exist in one person; that there are seven sacraments and four canonical gospels. But none of these numbers can be tested in laboratories. Nor can there be a laboratory test of the philosophical and theological tenet that the world was created out of nothing. There can be no such test because the nothing, insofar as it is radically no thing at all, cannot have observable and therefore measurable properties. For the same reason science cannot establish the first moment of cosmic existence. For to prove that moment to be truly first, one has first to show that nothing preceded it. Such is, however, a purely negative proviso that cannot be given a quantitative, that is, scientific verification. Nor is the universe as such an object for science. Scientists cannot go outside the universe in order to observe the whole of it and thereby give to their knowledge of the universe that supreme scientific seal, which is observation with measurement.

Moreover, the notion of the universe is the vastest of all generalizations, although in more than a purely quantitative sense. The notion of the universe is the supreme form of universals. Quantitative or experimental considerations, that always relate to the particular, remain wholly insufficient to justify the validity of the universals, including above all the universe. Indeed, no branch of modern science, with one exception (evolutionary biology, of which more shortly), is so fundamentally dependent on philosophy as is scientific cosmology, and in no other field of science is philosophy more ignored, and indeed scorned.

In scientific cosmology, insofar as it deals with various components of the universe such as galaxies and globular clusters, philosophy can be safely ignored. The scientist merely has to assume, on a commonsense ground, that those objects do exist because they are observ-

able. Only when it comes to the universe as such, do scientific cosmologists claim to know something whose existence only a rigorously articulated philosophy, respectful of the universals, can demonstrate.²⁵ But in evolutionary biology one comes across indispensable philosophical terms at almost every step. Concerning the species, it is something that cannot be observed. Yet it has to exist if it is right to talk about the origin and transformation of species. One can get around this problem, which involves the philosophical problem of knowing universals, by defining a species as the totality of all individuals that can interbreed. But when we go to the genus and to even higher units, up to families, orders, phyla, and kingdoms, that definition does not do. Again, only the great generalizing powers of the mind can enable the evolutionary biologist to see a continuous connection along the paleontological record, although, as recent findings show, it is more riddled with huge holes and discontinuities than ever suspected.

Yet most evolutionary biologists have only contempt for philosophy, although it alone can justify their great unifying vision, which is much more than science, strictly speaking. What they do is climb the rungs of an essentially philosophical ladder in order to see much farther than would be allowed, strictly speaking, by the data on hand. However, once at the top of the ladder, they haughtily kick it away. In doing so they follow the example set by Darwin. With Darwin they try to discredit philosophy with their science, although philosophy enabled them to raise their eyes to heights where biological evolution can be seen, though only with the eyes of the mind. No wonder that the present-day perplexity of some leading paleontologists evokes the fate of Humpty Dumpty.

But just as scientists cannot ignore philosophy, philosophers and theologians can only at their gravest peril ignore the fact that quantitatively verifiable parameters as such lie outside their competence. Herein lies a basic limit of theology, philosophy, and various branches of the so-called humanities. The truth of any philosophical and theological statement that contains experimentally verifiable quantities, depends on experimental or laboratory verification, with measurement being its very gist. This verification only science can provide. Conversely, genuinely philosophical statements cannot have a scientific verification, which always has to be experimental and therefore quantitative, derived from measurements.

Experimentally verifiable quantities represent a basic demarcation line between the sciences and other forms of reasoned discourse, such as philosophy, theology, and so forth. In essence this point was concisely stated already in the *Categories* of Aristotle. This is not to suggest that there is strict logic in his listing number and speech (syllables) as "discrete" quantities and space and time as "continuous" quantities. But there is a perennial truth in his observation that there is no common boundary between two numbers. Nor is it possible to dispute his statement that "the most distinctive mark of quantity is that equality and inequality are predicated of it." Consequently, within the Aristotelian perspective numbers do not admit contraries such as the ones that occur between celestial and terrestrial motion, as well as among the basic types of motion (upward and downward) below the orbit of the moon. Moreover, "quantity does not admit of variation of degree. One thing cannot be two cubits long in a greater degree than another. Similarly with regard to number: what is 'three' is not more truly 'three' than what is 'five' is five."²⁶

Leaving aside Aristotle's dicta on space and time, let alone syllables, it should be clear that equality and inequality are, unlike numbers, not absolute, but relative properties that

reflect our judgments of similarities among various things. These similarities cannot be translated into absolutely valid numerical propositions. To quote Aristotle: "That which is not a quantity can by no means, it would seem, be termed equal or unequal to anything else. One particular disposition or one particular quality, such as whiteness, is by no means compared with another in terms of equality and inequality but rather in terms of similarity."²⁷ But it is precisely this kind of similarity that does not lend itself to strict, invariably valid, numerical evaluation.

Aristotle's own examples are worth recalling. A mountain, though a huge entity, can be called small; and a grain, though puny, large. In both judgments comparisons or similarities are at play. Similarly, it is possible to say that a house has many people in it, whereas a theater only a few. All this is but an aspect of what Aristotle specifies, in taking up the discussion of qualities, as the rule of the "more or less." Whereas all qualities can be presented as containing "more or less" of what is distinctive of them, this cannot be said of numbers. Aristotle did not suspect that with the coming of science in the modern sense, that is, a science in which quantities rule supreme, this quality of "more or less," so characteristic of his own physical science, would have to be jettisoned.²⁸

While Aristotle correctly specified the most important feature of quantities, he himself did not pay proper attention to it as he set forth his accounts of the celestial and terrestrial world. There his "qualitative" physics led him, time and again, into implicitly quantitative, and at times explicitly quantitative inferences that could not be reconciled with what was plainly observed. Thus, it should have been obvious in Aristotle's time that bodies of greatly differing weights fall to the earth in remarkably equal times. Peripatetic physics could have indeed been held up to well-deserved ridicule long before Galileo's time.²⁹ It was another matter whether it was right for Galileo to invoke Plato's reification of numbers in order to justify that equality and other geometrical or numerical features discoverable in the physical world.

Unfortunately, Aristotle did not set a pattern as to the conclusions to be drawn from what he so incisively stated about quantities. Hence the pathetic opposition posed by Averroist Aristotelians to the new physics of motion. To be sure, even three centuries later one could still be puzzled by the fact that the law of inertial motion, in which there is at least the continued novelty of spatial displacement, "worked," although it provided no "explanation" of how the novelty came about.³⁰ Yet once one accepted with Aristotle the special status of numbers or quantities, it should have been possible to state that spatial displacement, as a purely quantitative proposition, implied no ontological factors. Not that these factors were denied by the mathematical formalism of inertial motion; rather, mathematics could have no bearing on them. This is no less true of the Newtonian law of accelerated motion. For that law too is independent of whatever philosophical or ontological definition one gives to the force being constantly at work in order to make real the acceleration. For what Hertz said about Maxwell's theory of electromagnetism, can also be stated of Newton's theory of gravitation: it is Newton's system of equations. Nothing more, nothing less.

But it still goes against the grain to recognize that there is an insurmountable conceptual obstacle to the age-old striving after a unified form of knowledge. That obstacle lies in the way of any form of reductionism, crude or refined, vicious or well-meaning. This is

not to suggest that there will soon be an end to efforts that want to reduce man, and all his thinking and volitions, to a machine. Scientific reductionism is as strong, if not stronger, than ever. But that obstacle also vitiates all efforts to "integrate" science with philosophy and theology. For if pathetic is the claim that qualities—in their broadest sense, that is insofar as they include value- and existence-judgments—can be reduced to quantities, so is the effort to wring some theological truth out of any result of classical or modern physics. The reason lies in what Aristotle had already stated concisely about the unique status, among all categories, of the category known as quantity.

There is indeed an inefaceable line of demarcation between the conceptual domain of quantities and all other conceptual domains taken together. The conceptual domain of quantities is a most special domain that stands apart from the rest because all terms belonging to it have a peculiarly common characteristic. They all are strictly univocal, to use a term that, though increasingly unfashionable, never becomes antiquated. Quantities are like so many building blocks with well-defined contours. The coordination of those blocks can, of course, be exceedingly complex and complicated. This is brought out by a mere look at any advanced textbook of mathematical physics. But whatever that complexity and complicatedness, the art of handling those blocks—quantities—follows invariable rules. The art is always the same, because the art is a skill with the basic operations of arithmetic.

One can, of course, philosophize about quantities, but the operations performed with quantities have their own independence, precisely because quantities have a specific conceptual character that makes them distinct from all other concepts. All conceptualizations of numbers can be compared to strictly defined building blocks that remain forever identical to themselves. This is why their addition, subtraction, multiplication, and division are a straightforward matter, in principle at least. All other concepts are amoebas by comparison, or even less definite. For amoebas, although they constantly change, have a strict boundary membrane. Non-quantitative concepts have neither permanent shapes, nor distinct envelopes. This is why their definitions given in any dictionary are forever subject to slight and, at times, drastic rewriting.³¹ This is what Whitehead wanted to convey in warning against the dream of a "Perfect Dictionary."³²

What is actually being done in giving the dictionary definition of a word is to define it in terms of some other words. In the case of quantitative concepts, say a number, such as twenty, one juxtaposes so many unit areas. Thus the concept of twenty is the sum of twenty units. To represent any number other than one may be done either by the addition or the multiplication of the unit area. The starting point is always the unit integer. But there is no such strictly defined starting point when one defines non-quantitative words or concepts. There one has to superimpose partially several non-quantitative concepts, each corresponding to a given area which is not strictly circumscribed. Therefore that superimposition is never absolutely fixed or definite, partly because the words constituting the definition do not have distinct contours. Any definition of a non-quantitative concept may therefore best be compared to the partial superimposition on one another of, say, six or seven patches of clouds whose contours vanish at their presumed boundaries. The meaning of the concept then corresponds to the area where all the concepts used in the definition overlap. But the area of that overlap is not strictly definite.

When viewed from a distance, such an overlap, like any cloud, appears with distinct edges. This is why non-quantitative concepts function well in ordinary discourse. But when they are subject to a close analysis, they seem to evanesce. Such is the reason for the intellectual malaise created by logical positivism. On more than one occasion it prompted despair about the possibility of knowing anything at all. One wonders whether A.J. Ayer knew the true reason why he had to admit that almost everything was wrong with logical positivism.³³ The reason was the presumption that every good reasoning should be a "scientific" reasoning. In other words, logical positivists looked for strictly defined conceptual building blocks even within the non-quantitative realm, although there only patches of fog could be found.

Yet those non-quantitative concepts do not become less real, just because it is not possible to ascribe them quantitatively exact contours. Patches of fog are just as real whether looked at from a distance or from close range. Thus the notion of forest does not become invalid just because a forest, when looked at close range, merely shows single trees. Nor does the notion of forest become invalid just because it is not possible to define quantitatively the number of trees that would constitute not merely a grove but a forest. It is not possible to find the number of pages that would necessarily constitute a book and not a mere pamphlet. It is quite an arbitrary matter when librarians, in their despair, decide that 60 pages are needed at the minimum to make a book.

While no superimposition of patches of clouds would turn them into the kind of building blocks which quantities are, quantities would not remain quantities once deprived of their strict conceptual contours. This radical difference between quantities and everything else is still to be perceived in its true weight by champions of artificial intelligence, these latter-day protagonists of reductionism. While quantitative concepts can be given "exact" equivalents in the magnetic orientation of ferro-silicate domains within the chips, this cannot be done with non-quantitative concepts that represent the overwhelming proportion of human conceptualizations. They include the crucially important value judgments and existence judgments.

While this basic difference between quantitative and non-quantitative concepts may appear madness from the viewpoint of artificial intelligence, the human mind has no problem in living with that difference. It is an often underestimated marvel of the human mind that it can understand with equal ease quantities and qualities, an ease incomprehensible within the perspective of artificial intelligence programming. The human mind can grasp in a single act of knowledge entities, for instance, an aesthetically valuable painting, that convey ideas both quantitative and aesthetical at the same time and in the same act of perception. The mind is not disturbed by the fact that a human action, such as a step forward, is fully describable in quantitative terms, and yet non-describable in those terms insofar as that step was made really and freely, and for a purpose.

In order to awaken the minds of my readers and audiences to this fundamental fact of irreducibility, I used to present them with a paradoxical—but I hope not irreverent—twist to a statement in the gospel. The statement is well known: What God has joined together, no man should separate. Twisted, the phrase would go: What God has separated, no man should try to fuse together, lest confusion should arise. Human knowledge, whether we consider it to have come from the hands of God or not, concerns two separate realms,

quantities and non-quantities, and these two realms are irreducible to one another. It is not profitable for man to chafe under that restriction. Those who did, whether on the Hegelian right or the Hegelian left, created only confusion for themselves and others.

About quantities, insofar as they are embodied in matter and drawn out of it by measurements and mathematical operations, science alone is competent. In that sense, and in that sense alone, science is unlimited, while remaining limited to quantities. All other considerations that relate to non-quantitative features, are beyond the quantitative competence of science which is its sole competence. Conversely, quantitative considerations, insofar as they are to be empirically verified or measured, are beyond the competence of philosophy or theology, to mention only the principal fields of inquiry that do not aim at measuring anything in sensible matter.

This distinctness between the quantitative and non-quantitative (qualitative) realms of knowledge is not proposed as a starting point in knowledge. Sensory knowledge begins with the registering of external reality, or things in short. This is true even though what is most directly perceived in things is their size. This is why the category of quantities holds first place among all categories. Or as Aquinas states, "accidents befall substance in a definite order. Quantity comes to it first, then quality, after that passivities and actions." To continue with Thomas, "sensible qualities cannot be understood unless quantity is presupposed...and neither can we understand something to be the subject of motion unless we understand it to possess quantity."³⁴

This primary position of quantities among all categories is the reason for their conceptual isolation among them. Quantities do not admit analogical degrees of understanding. This constitutes their radical difference from other categories and even from substance and existence. Herein lies the error of those who, with Heisenberg in the van, tried to see in wave mechanics something analogous to the Aristotelian doctrine of potency.³⁵ One should therefore take it for distinct progress that physics has ceased to be called natural philosophy.

The inseparability of quantities from matter justifies the quantitative character of the scientific method. Compared with it, all other considerations about science are of secondary importance, no matter how intriguing they may be. Unfortunately, for the past thirty years or so, interpretations of science have been dominated by these secondary considerations. We have learned a great deal about the psychological aspects of scientific discoveries. We have learned much about sociological factors that promote or hinder scientific progress. We have learned a great deal about paradigm shifts, research programs, scientific styles, and so forth. But because the basic feature as outlined above has not been kept in focus, a great deal of confusion has arisen about science. One result of that confusion is the view that Taoist meditation is the chief propellant of the great insights of modern physics. To see that confusion for what it is, it is enough to contrast the definiteness of numbers (including quantizations of the energy levels in the Bohr atom) with the indefiniteness of both Yin and Yang in their mutual interactions.

To cut through that confusion one need not be a scientist, one need not even be a philosopher of science. One need only to remember the role of quantities in science. It takes no advanced mathematics to ask about any proposition, whether it includes quantitatively determinable parameters. Inasmuch as it does, it is a scientific proposition. There science, insofar as it verifies or disproves theories in their quantitative inferences, alone is

competent. Insofar as that proposition contains parameters other than quantitative, other branches of human discourse—philosophy, theology, esthetics, or whatnot—should be resorted to in order to evaluate them.

This multiple approach demands mental discipline in no small measure. First of all, the scientist should be aware of the fact that even the most appealing procedure may not be free of ambiguities. Symmetry in equations may seem to recommend itself on aesthetic grounds as an unquestionably worthy and fruitful goal. Yet those grounds will appear somewhat shaky as soon as one considers that there is nothing symmetrical in the “golden cut” or golden proportion in which ancient and modern artists have recognized something profoundly aesthetic. Also, an absolutely perfect symmetry is not applicable in relation to a physical universe in which nothing would move if there were not some basic imbalance built into it.

To overlook such ambiguities will not come easily to those whose chief training is in the one-way thinking of quantitative method and in nothing more complicated. They will be swayed time and again by the staggering measure to which matter can be manipulated through its quantitative properties. Science extends to wherever quantitative properties can be found and is competent to handle them. Beyond that, science is not only incompetent, but may be the source of most dangerous expectations. I have often stated that over the entrance of every laboratory and department of science one should carve the words of Maxwell, which I quoted above, about the severest test of the scientific mind. To those words should be joined a warning by Polykarp Kusch, a Nobel-laureate physicist. “Science,” he said, “cannot do a very large number of things, and to assume that science may find a technical solution to all problems is the road to disaster.”³⁶ To safeguard against such a disaster few considerations may be more effective in this scientific age than a reflection on the limits of an otherwise limitless science.

NOTES

1. As told by C.P. Snow, “The Moral Un-neutrality of Science,” *Science* 133 (1961), p. 257.
2. Lord Kelvin, “Electrical Units of Measurements” (1883), in *Popular Lectures and Addresses* (London: Macmillan, 1891-94) 1:72-73.
3. R. Mayer, “Ueber notwendige Konsequenzen und Inkonsequenzen der Wärmemechanik” (1869) in *Gesammelte Schriften* (Stuttgart, 1893), p. 355.
4. Letter to Greisinger, July 20, 1844, in *Die Mechanik der Wärme in Gesammelte Schriften* (Stuttgart, 1893), p. 145.
5. A. Einstein, “What Is the Theory of Relativity?” in *The World as I See It* (New York: Covici, 1934), p. 80.
6. See E. Warburg, “Friedrich Kohlrausch: Gedächtnisrede,” in *Verhandlungen der Deutschen Physikalischen Gesellschaft* 12 (1910), p. 920.
7. For details, see my *The Relevance of Physics* (Chicago: University of Chicago Press, 1966), pp. 127-30.
8. See E. Fuller (ed.), *2500 Anecdotes for All Occasions* (New York: Avenel Books, 1978), p. 192.
9. H. Hertz, *Electric Waves*, D.E. Jones, trans. (London: 1893), p. 20.
10. R. Feynman, R.B. Leighton, M. Sands, *The Feynman Lectures on Physics* (Reading, Mass.: Addison-Wesley, 1964), vol. II, section 41, p. 12.
11. *Ibid.*
12. See my review, “Mind: Its Physics or Physiognomy?” (1991) of Penrose’s book, in my

Patterns or Principles and Other Essays (Bryn Mawr, Pa.: Intercollegiate Studies Institute, 1995), pp. 204-213.

13. As I argued in my review of Hawking's book, "Evicting the Creator" (1988), reprinted in my *The Only Chaos and Other Essays* (Lanham, Md.: University Press of America; Bryn Mawr, Pa.: Intercollegiate Studies Institute, 1990), pp. 152-161.

14. See my *God and the Cosmologists* (Edinburgh: Scottish Academic Press, 1989), pp. 138 and 258. New enlarged edition also by Real View Books (Fraser, Mich.: 1998).

15. D. Hume, *An Enquiry concerning Human Understanding*, Section 12, part 3. In *Philosophical Works* (1826), 4:193.

16. In a conversation with Camap. See the latter's "Intellectual Autobiography," in P.A. Schilpp (ed.), *The Philosophy of Rudolf Carnap* (La Salle, Ill.: The Library of Living Philosophers, 1963), pp. 37-38.

17. Just as Einstein viewed, in the name of science, free will as illusion, so did he view any abiding sense of human purpose and, of course, the immortality of the soul. For details and documentation, see my *The Purpose of It All* (Lanham, Md.: Regnery Gateway, 1990), pp. 182-83. Italian translation, *Lo scopo di tutto* (Milano: Ares, 1994).

18. "C'est librement qu'on est déterministe," goes Poincaré's priceless phrase in his essay, "Sur la valeur objective des théories physiques," *Revue de métaphysique et de morale* 10 (1902), p. 188.

19. Reported in *Trenton Times Advertiser*, February 25, 1995, p. 1.

20. Reported in E. Gilson, *From Aristotle to Darwin and Back Again. A Journey in Final Causality, Species, and Evolution*, J. Lyon, trans., with an introduction by S.L. Jaki (Notre Dame, Ind.: University of Notre Dame Press, 1984), p. 28.

21. A point wholly ignored in standard high-level popularizations of brain-mind research, such as D. J. Chalmers, "The Puzzle of Conscious Experience," in *Scientific American* (December 1995), pp. 80-87.

22. W. Quine, "Ontology and Ideology Revisited," *The Journal of Philosophy* 80 (1983), p. 1.

23. In numerical terms the efficiency in question is 16 percent.

24. See *The Scientific Papers of James Clerk Maxwell*, ed. W.D. Niven (Cambridge, 1890), vol. II, p. 759.

25. See chs. 5 and 6 in my book, *Is There a Universe?* (Liverpool: Liverpool University Press, 1993).

26. *Categorias*, 6a. I am quoting the English translation in *Great Books of the Western World*.

27. *Ibid.*

28. Those who, in imitation of A. Koyré, contrast in such a way pre-modern with modern science, usually fail to refer to that phrase of Aristotle who himself overlooked its import in dealing with the physical universe.

29. For a list of plain absurdities in Aristotle's physics, see my *The Relevance of Physics*, pp. 26-28.

30. This puzzlement is the gist of the exchange of letters between Pierre Duhem and R. Garrigou-Lagrange. See my article, "Le physicien et le métaphysicien. La correspondance entre Pierre Duhem et Réginald Garrigou-Lagrange," *Actes de l'Académie Nationale des Sciences, Belles-Lettres et Arts de Bordeaux*, 12 (1987), pp. 93-116.

31. See my paper, "Words: Blocks, Amoebas, or Patches of Fog? Some Basic Problems of Fuzzy Logic." *Proceedings of the International Meeting of the Society of Photo-Optical Instrumentation Engineers, Orlando, Florida, April 10-12, 1996*, ed. B. Bosacchi and J.C. Bezdek (Bellingham, Wash.: SPIE, 1996), pp. 138-143.

32. See A.N. Whitehead, *Modes of Thought* (1938; New York: Capricorn Books, 1958), p. 235.

33. Quoted in B. Magee, *Men of Ideas: Some Creators of Contemporary Philosophy* (London: British Broadcasting Corporation, 1978), p. 131.

34. St. Thomas Aquinas, *The Division and Methods of the Sciences. Questions V and VI of his*

Commentary on the De Trinitate of Boethius. Translated, with introduction and notes by A. Maurer (4th rev. ed.; Toronto: Pontifical Institute of Medieval Studies, 1986), p. 40 (Qu. V. art. iii).

35. For details, see my *God and the Cosmologists*, pp. 155-56.

36. Address to the Pulitzer Prize jurors, Columbia University, 1961, in *New York Herald Tribune*, April 2, 1961, sec. 2, p. 3, col. 5.

