THE ROLE OF FAITH IN PHYSICS

by Stanley L. Jaki

A little over seventy years ago, in 1896, the founder of psychology in America, William James, spoke before the philosophical clubs of Yale and Brown. The title of his still-famous lecture was "The Will To Believe." Its topic, as James noted with tongue in cheek, was hardly in line with what he called "Harvard freethinking and indifference."[1] In fact, a year later, when sending his lecture to print, he felt the need to explain why he had spoken of faith to an academic audience. He knew that according to most of his colleagues modern conditions required not stronger beliefs but a keener sense of doubt and criticism. Yet, James did not consider it "a misuse of opportunity" on his part to emphasize the role of faith before a gathering of scholars. He admitted that credulous crowds needed to be exposed to what he called "the northwest wind of science." For intellectuals, however, he had the following diagnosis: "Academic audiences, fed already on science, have a very different need."[2] What they needed, according to him, was the will to believe.

It is rather a reassuring symptom that, today, academic circles suffer much less of what James called "a paralysis of their native capacity for faith."[3] The recognition is growing strong that faith, or belief, forms the ultimate foundation of the certainty of every knowledge.[4] Such is certainly the case in the field of physics. Leading physicists voice with ever greater emphasis the conviction that faith plays an indispensable role in their search for new discoveries. Their awareness is steadily growing that historic breakthroughs in physics are as much the product of a trusting faith in nature as of a critical analysis of the facts of nature. Most important, leading physicists of today know all too well that the products of science will ruin mankind unless science will foster man's faith in himself and in his goals.

In speaking about faith, one touches on a delicate subject that

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needs clarification, especially when related to the science of physics. No one in his right mind will have any use for a faith as defined by a schoolboy: "Faith is when you believe something that you know isn't true." Clearly, to believe in something because it is absurd would be even worse than to believe blindly, which is bad enough. One may indeed go along with the dictum of T. H. Huxley who called "blind faith the one unpardonable sin."[5] Where Huxley, however, cannot be followed, is in looking with suspicion on faith in general. Faith can, of course, be blind, but so can unbelief, and Huxley himself was blinded by a false image of science very fashionable in his day. In 1866, when Huxley made his statement, physics seemed to approach rapidly its final and perfect stage. In 1871, Lord Kelvin told the British Association that the successes of the kinetic theory of gases pointed to an early completion of an all-inclusive, definitive physical theory.[6] Two decades later, another prominent British physicist, Oliver Lodge, interpreted the success of Maxwell's electromagnetic theory in the same sanguine way. As Lodge put it: "The present is an epoch of astounding activity in physical science. Progress is a thing of months and weeks, almost of days. The long line of isolated ripples of past discovery seem blending into a mighty wave, on the crest of which one begins to discern some oncoming magnificent generalization."[7]

Neither Oliver Lodge, nor Lord Kelvin, nor Huxley guessed that, instead of a major and final triumph, agonizing discoveries were in store for physics. Discoveries were to come that played havoc with apparently absolute tenets in physics. The last decade of the nineteenth century saw the discovery of radioactivity and of X-rays. Finally, only a short three weeks before the century was out, there came Planck's announcement of the concept of the quantum of energy. The concept, as all students of physics know, stood in fundamental opposition to some basic tenets of classical physics. The concept of quantum contradicted the principle of continuity, or endless divisibility of matter, and it also contradicted the principle of strict, physical causality. Abandoning those principles seemed equivalent to abandoning the conviction that nature itself was orderly and intelligible. Planck himself was beset with the most serious misgivings. As a matter of fact, he explored every possible avenue to find fault with his famous derivation of the formula of energy distribution of blackbody radiation.

But the concept of quantum could not be evaded. And what an ominous concept it was. It seemed to suggest that, if nature was orderly, its orderliness was beyond the reach of classical physics. But was there at that time any other physics than the classical? In the context of the times, all this seemed to mean that the orderliness of nature could not be grasped by science. As a result, the concept of quantum presented physics with a tremendous challenge. The challenge was the challenge of faith. It called for a step in the dark; it called for a step beyond the science of the day into a mysterious new land of inquiry. It was a challenge that demanded faith in the absolute orderliness of nature regardless of whether the best of science was up to it or not. Such at least was the situation as it appeared to Planck himself. To live with such a situation, to cope with it and to master it, became for him the most momentous experience of his life. It was this experience that prompted his statement of faith, which is worth being quoted in full: "Science demands also the believing spirit. Anybody who has been seriously engaged in scientific work of any kind realizes that over the entrance to the gates of the temple of science are written the words: *Ye must have faith.* It is a quality which the scientist cannot dispense with."[8]

Quantum theory is one of the two main pillars of modern physics. The other is the theory of relativity. These two theories are still unrelated. Today the so-called Unified Theory is but a dream, not a reality. There was, however, a basic common ground in the thinking of the authors of those two theories. Albert Einstein, the principal originator of the theory of relativity, was just as emphatic as Planck was in stressing the importance of faith in the work of the scientist. This is easy to understand. Relativity, no less than quantum theory, demanded an entirely new outlook on nature. The acceptance of relativity meant the abandonment of absolute space and time. In their place came a space and time defined in terms of the frame of reference of the observer. No wonder that idealist philosophers saw in relativity a vindication of their claim that the order in nature was merely a subjective construct of the mind. Such were not, however, Einstein's views. For him, relativity meant rather the conviction that the laws of nature are always and everywhere the same, regardless of the frame of reference one may choose. He viewed the constancy of the speed of light as an absolute, primordial fact of nature that existed, with the rest of nature, independently of the thinking mind. Furthermore, he insisted that the scientist must have full confidence in the objective existence of nature. "Belief," he wrote, "in an external world, independent of the perceiving subject, is the basis of all natural science."[9] It was the same idea that he articulated in greater detail in his analysis of the history of physics written jointly with Leopold Infeld. "Without the belief that it is possible to grasp the reality with our theoretical constructions, without the belief in the inner harmony of our world, there could be no science. This belief is and always will remain the fundamental motive for all scientific creation."[10] To Einstein, the nature of this faith was such as to put it into the sphere of religious beliefs. As he emphatically argued the point, the man of science needed no less than a "profound faith" to secure for himself the assurance that "the regulations valid for the world of existence are rational, that is comprehensible to reason." A scientist without that faith was simply beyond his comprehension. Clearly, such a disclosure of his thoughts had to come from the deepest recesses of his convictions. The measure of that depth can be best gauged in his most famous aphorism: "Science without religion is lame, religion without science is blind."[11]

Next to quantum theory and the theory of relativity, the most outstanding creation of twentieth-century theoretical physics is Eddington's *Fundamental Theory*. Its purpose was possibly the most ambitious ever offered in the history of science. In substance, Eddington tried to derive from purely epistemological considerations the basic structure and fundamental laws of the universe. Thus he claimed to have established on a priori grounds that the total number of protons in the universe was of the order of 10^{79}. Eddington's ideas did not produce many disciples; yet even his most severe critics expressed their admiration for his bold efforts. At the basis of that intellectual boldness there stood an extraordinary measure of faith—faith in the orderliness of nature, and faith in the ability of the inquiring mind. Or as Eddington put it: "Reasoning leads us from premises to conclusions; it cannot start without premises; . . . we must believe that we have an inner sense of values which guides us as to what is to be heeded, otherwise we cannot start on our survey even of the physical world. . . . At the very beginning there is something which might be described as an act of faith—a belief that what our eyes have to show us is significant."[12] Long would be the list of twentieth-century physicists who spoke in the same vein. Let it suffice here to recall only a few outstanding cases. First, Heisenberg, whose indeterminacy principle showed the full depth of Planck's quantum theory. He spoke of faith as the perennial mainspring of scientific work.[13] Willem De Sitter, one of the original proponents of relativistic cosmological models, also found it important to stress that "without a solid faith in the existence of order and law no science is possible." Moreover, he was also very explicit in stating that such belief, forming the basis of science, "is not a scientific theory." It is not derived, he insisted, from science, but rather "it is prescientific, being rooted much deeper in our consciousness than science, it is what makes science possible."[14]

THE INFERNAL RACE

By referring to the concept of the possibility of science, De Sitter touched upon a point that deserves to be discussed in some detail. Most immediately, the expression "possibility of science" refers to that historic event known as the birth of science. More of that later. But the expression "possibility of science" refers also to that series of options which runs unbroken throughout the entire history of science. Of this, physicists working in the forefront of physics are fully aware. They are the ones who stand on the borderlines of the unknown. For them, the possibility of science implies a constant renewal of their faith in the orderliness of nature. The best illustration of this can be gathered from a quick glance at what goes on in high-energy physics, or the search for fundamental particles. It is a bewildering field. Hardly a month passes today without the discovery of a new particle, or resonance, or whatever name you may prefer. Theories trying to systematize those particles are succeeding one another with astonishing rapidity. The reason for this lies in the now historic pattern: each major advance in accelerator construction has brought into view new, unsuspected particles. As a physicist put it, high-energy physics seems to be caught up in an infernal race.[15]

The expression "infernal race" was well chosen from the psychological viewpoint at least. In such a race there is hardly any room for certainty or relaxation. Today, physicists think back with embarrassment to times when the last layer of matter was believed to be within reach. In our century the opening decade, the early thirties, and the fifties were such times. Thus in the early thirties the proton, neutron, and the electron were believed to have formed the fundamental system of particles. In the fifties most physicists believed that nature was built on a system of some thirty-four fundamental particles. Today, it is admitted that the best established property of fundamental particles is that none of them is fundamental. In one word, the final layer of matter appears to be farther away than ever. Recently, at the February, 1967, meeting of the American Physical Society, its president, Professor J. A. Wheeler of Princeton University, took the view that the ultimate layer of matter might be located in a practically never-never land, at the level of the so-called Planck distance, which is of the order of 10^{-33}cm.[16] How soon science will edge down to that level is anybody's guess. Perhaps in a hundred years. Even so it will be an extraordinary achievement. After all, during the last half-century, science only managed to move from the atom (10^{-8}cm.) to the neighborhood of the radius of the nucleus, that is, to the neighborhood of 10^{-13}cm. This great advance covered only five orders of magnitude. Between the nucleus and the realm of Planck's distance there are, however, twenty orders of magnitude. In addition, one should not forget that the smaller a spatial magnitude is, the greater energy is required for its exploration. Whether energies necessary for the investigation of the realm of Planck's distance shall ever be available is a moot question. Furthermore, can science be assured that upon reaching that realm it would find exactly what it looked for? Very likely not. Clearly such is not a comforting outlook. It certainly gives no one the right to make easy predictions. Still the work of research must go on. And it is well to remember that its ultimate sustaining force is faith. Or to hear a prominent physicist, the late director of the Institute for Advanced Study, Robert Oppenheimer, state it: "We cannot make much progress without a faith that in this bewildering field of human experience [particle research], which is so new and so much more complicated than we thought even five years ago, there is a unique and necessary order; not an order that we can see without experience, not an order that we can tell a priori, but an order which means that the parts fit into a whole and that the whole requires the parts."[17]

Ten years have passed since Oppenheimer made this statement of faith. Those ten years were an era of feverish research, yet none of the results diminished either the beauty or the truth of his words. No physicist can tell us today what are the true parts of the ultimate system of particles; yet, all believe firmly in the existence of such a system. This faith of theirs is not an easy one. After all, they are everyday witnesses to the fact that assuredly stable particles turn out to be subject to decay. Thus the concept of finality or definiteness has taken on for the modern physicist a meaning wholly different from its obvious meaning. Finality is to be taken today in physics as largely provisional. It ought to be most puzzling for the modern physicist to find that it is his own tools that time and again deprive him of apparently firmly established grounds. These tools are the tools of precision. They both confirm and undo theories, and keep physics in a dynamic flux never experienced before. These tools create as many problems as they provide solutions. For all that, the physicist must retain his confidence in the double-edged sword of precision, which keeps opening up before him strange, perplexing worlds. In using the tools of precision, all physicists are sustained by faith. It holds of all of them what was true of Albert A. Michelson, a wizard of precision in measurements and the first American to receive the Nobel Prize in physics. As Millikan, another Nobel laureate, said of Michelson: "He merely felt in his bones or knew in his soul, or had faith to believe that accurate knowledge was important."[18]

It was more than forty years ago that Millikan uttered these words. In American science and scientific philosophy, the thirties were still an era dominated by cliché accounts of the history of science. It was an era that accepted without further ado the slogan that physics consisted solely in correlating data of observations and experiments. The word "faith" was an ugly word for most of those who in those years and until very recently posed as the supreme interpreters of science and were accepted as such. I have in mind the neopositivists and the operationalists. There is, of course, much that can be said in favor of operationalism and of logical positivism. When, however, taken as the fundamental and exclusive theories of science, they display a serious shortcoming. Operationalism and logical positivism do not square with the facts of scientific creativity. In our times this was emphasized by such creative personalities of physical science as Einstein, Born, Schrödinger, and many others.[19] It was in fact in the wake of his discovery of wave-mechanics that Schrödinger decried "that cold clutch of dreary emptiness" which exudes from the definition of scientific work as given by positivism: a description of the facts, with the maximum of completeness and the maximum economy of thought. Scientists sufficiently honest with themselves, Schrödinger added, would admit that "to have *only* this goal before one's eyes would not suffice to keep the work of research going forward in any field whatsoever."[20]

Much less could the positivistic concept of science give start to the scientific endeavor itself. No wonder that the very start, the birth of science, has not become a favorite topic with positivist historians of science. Indeed, there can be no satisfactory explanation for it within a framework that frowns on the mental attitude called faith. Within the positivist framework it must remain an insoluble puzzle why science was born in the Western world and not in China or India or among the Mayas and the Aztecs. The birth of science was, of course, a rather long process. Its beginnings credit the marvelous insights of the Greek mind. As Einstein once noted: "In my opinion one has not to be astonished that the Chinese sages have not made these steps [the major discoveries of Greek science]. The astonishing thing is that these discoveries were made at all."[21] Still for all its achievements, ancient Greek science is not without a grave puzzle. That puzzle derives from the fact that Greek science remained a half-way house. It failed to recognize the crucial role of systematic experiments. It proved itself wholly powerless to come to grips with the quantitative analysis of motion.

The Birth of Science

It is a fact of scientific history that man needed faith to overcome these hurdles and to bring science to a full birth. It is a fact of scientific history that the birth of modern science took place in a cultural ambiance wholly permeated by belief in dogmas. Foremost of these was the Christian tenet about a personal, rational Creator of the universe. Our century was reminded of this by Whitehead in his Lowell Lectures of 1925, published under the title, *Science and the Modern World.* To millions of readers of that book it came as a revelation that, contrary to the claims of positivism, science does not owe its origin to the rejection of religious beliefs. Instead, as Whitehead told his readers, they had to look for the birth of science in the staunch belief of the Middle Ages. Foremost in this respect was, according to him, the medieval insistence on the rationality of the Creator. Whitehead also emphasized that belief in the dogma of creation had to be shared by a whole culture throughout several generations. Only such communal experience and conviction could produce what Whitehead called a tone of thought, a climate of intellectual confidence and courage.[22] This in turn gave rise to the scientific enterprise and determination to look for rationality in every process of nature.

In Whitehead's classic discourse, only one point was missing. He should have called his listeners' and his readers' attention to the fact that what he said was not a more or less subjective version of history. He should have told them that his ideas were but the echo of those men of science who witnessed the birth of science three to six centuries ago. Thus references to the Creator are explicit in the great medieval forerunners of modern science, such as Oresme and Buridan. Their statements were further elaborated by such theoreticians of sixteenth-century science as Descartes, Bacon, and Galileo. Bacon's writings in this respect are especially instructive. Not a particularly original thinker, Bacon had an uncanny sense of gathering the best that was available in his time. He also had the skill to elaborate on it with great persuasiveness. Most of all, he said what his contemporaries wanted to hear. They wanted to hear, for instance, why Greek science came to a standstill. For the failures of the Greeks, Bacon laid the blame on the pantheistic features of their religious views.[23] It was pantheism that put the theological seal on the Greeks' preference for viewing the world as an organism, or a huge animal. For them, each portion of the world was full of volitions closely paralleling human strivings and aspirations. They discussed the fall of stones, the rise of fire, the motion of the stars in the same breath with the motion of animals. For them, man was but a tiny organism wholly subject to the countless volitions animating the whole cosmos. Obviously, such an outlook could not generate a sustained confidence in ever deciphering, let alone mastering, the whims and movements of that great animal, the entire universe.[24]

On the sad failure of Greek science, an unexpected light is thrown by recent investigations of Chinese scientific history. What I have in mind is the conclusion of J. Needham, the distinguished author of the most monumental study of the history of Chinese science ever published in the West. A Marxist, Needham looked in various socioeconomical factors for the likely cause of the failure of the Chinese to invent science, so to speak. As is well known, ancient and medieval Chinese, though very proficient in practical inventions, such as rockets and compasses, failed to formulate one single law of physics. As might be expected, Needham laid part of the blame on medieval Chinese feudalism and other so-called reactionary factors. Yet, according to Needham, the fundamental reason for the scientific failure of the Chinese lay somewhere else. He had to admit that the basic cause of that failure pointed to theology. More specifically, he called attention to the early loss in Chinese religious thought of the belief in a personal rational Creator. With the loss of that belief was also lost the faith, the confidence of the Chinese in the ultimate rationality of the universe. To quote Needham, "Among the Chinese there was no conviction that rational personal beings would be able to spell out in their lesser earthly language the divine code of laws which the Creator had decreed aforetime."[25]

It was not, therefore, a freak happening of history that science was born in a Europe that was living through its centuries of faith. It was a Europe where those lived and worked who looked upon the world as the product of a most rational Creator and looked upon themselves as the stewards of their Father's handiwork. Theirs was not a blind faith, and happily for them. For the twist of history thrust upon them the whole Greek scientific corpus within the short span of two generations. What hit them was nothing short of an intellectual deluge. All of a sudden they were challenged by the dazzling scientific works of a Euclid, of a Ptolemy, and of an Aristotle. Some of the passages they could not translate, let alone understand. But they did not panic. Instead, they read those books with eager enthusiasm, notwithstanding the fact that Rome at one time put a ban even on the works of Aristotle. The enthusiasm of the medievals is easy to understand. They believed themselves to be children of an all-powerful, all-reasonable, all-good Creator. Consequently, they had to be enthusiastically confident in the final outcome of their newborn quest for scientific knowledge.

Faith in Order

The quest of science has seen many triumphs and many agonies. They usually went hand in hand and evidenced equally well the role of faith for science. The first major triumph was Copernicus' outline of the planetary order. He was far from proving definitely the heliocentric proposition. But what he lacked in physical proofs, he amply supplemented with his faith in nature. From his belief that nature was the handiwork of the Creator, he readily concluded that nature was simple. His system of the planets, it is well to recall, gave no better prediction of the motion of planets than did Ptolemy's; the most attractive proof of Copernicus lay in the geometrical simplicity of the new ordering of the planets. It was a bold view, and he clung to it though its consequences flew in the face of everybody's daily experience. Positivists of all times may shake their heads in disbelief, but Galileo, whom they consider the father of experimental method, praised Copernicus precisely for what he did: for staying with his belief at the price of committing rape of his senses.[26]

These words of Galileo are not without some irony. Though he praised the faith of Copernicus, he did his best to conceal the fact that much of what he claimed in the *Dialogues* was still largely a matter of faith. He passed over in silence the fact that his unbounded admiration for geometry was in effect a loud profession of his faith in the geometrical ordering of nature. Mystic as he was, Galileo frowned on anything savoring of mysticism, and soon developed a dislike for Kepler, an unabashed mystic. The loser was Galileo. Had he referred in his *Dialogues* to Kepler's Laws, he might have considerably strengthened his cause. Also, his conflict with some churchmen might have taken a different course if it had been recognized that there is a role for faith in science and that theology does not operate by faith alone.

When the clash came to a head, Kepler was already dead. Perhaps he could have testified that his three laws were the outcome of tedious computations as well as of his firm faith in the mathematical orderliness of the universe. For this, no one gave him greater credit than Max Planck. In fact, Planck found a startling analogy between his case and Kepler's struggles. In Planck's case, the data of blackbody radiation were available to a great number of his colleagues. Yet, only one, Planck himself, perceived the true pattern underlying those data. And Planck was not ashamed to ascribe that success to his faith. Now, as Planck analyzed Kepler's case, both Tycho Brahe and Kepler were in possession of the same data of planetary motions. Yet, only Kepler found their true correlation. The answer to this could not be clearer to Planck. As he put it, Tycho did not have what Kepler did possess: scientific faith.[27]

That scientific faith is in evidence in all major breakthroughs and principal tenets of science. Men of science had believed in the inverse square law of gravitation long before its truth was demonstrated. Maupertuis had believed in his law of least action years before he formulated it with enough clarity. The law earned him the ridicule of the rationalist Voltaire, who decried it as credulous metaphysics. Yet, ultimately, it was Maupertuis' faith that proved victorious. It received its due praise when Helmholtz discussed the law of least action in 1884 before the Berlin Academy of Sciences. There Helmholtz traced the origin of the law to Maupertuis' belief in the uniformity of nature and in the human mind's ability to find the true form of that uniformity.

That Helmholtz saw Maupertuis' efforts in this light is understandable. Faith was the mainspring of his efforts to have the law of the conservation of energy recognized. His was not an easy struggle. His now classic paper, "On the Conservation of Force," was rejected by the leading German physical review. In the long run, however, the faith of Helmholtz prevailed. And so did the faith of Faraday and of other great physicists who worked on proving that all forces of nature are interconnected. In the case of electricity and magnetism, Faraday's was a complete success. On the other hand, only failures accompanied his lifelong efforts to find a correlation between electromagnetism and gravitation. For all that, the entries in his notebooks on the subject never showed the slightest trace of wavering. All the failures, he remarked, "do not shake my strong feeling of the existence of a relation between gravity and electricity." One of his papers on the subject refers to "the full conviction" and, again, "to the same deep conviction" that animated his search for a connection between gravity and electricity. To follow the promptings of that "strong feeling" was in his view a most sacred scientific duty. The contrary course, that is, to leave the problem untouched seemed to him equivalent to abandoning faith in nature or, to quote his words: "to rest content with darkness and to worship an idol."[28]

Fortunately for science, Faraday's faith, or "strong feeling," or "full conviction" in the interconnectedness of the forces of nature is as alive as ever. Witness Einstein's thirty years of search for a Unified Theory; witness the efforts to find a connection between the nuclear force and the force of the so-called weak interactions. Or witness the rather recent competition for the best essay on the possibility of gravitational shielding.[29] The idea underlying the competition was that, if there is a shielding against electrical forces, the same should also be true of gravitation. Faraday, I am sure, would have found to his liking a contest of this type and most likely would have participated in it with a lengthy paper. He would have also found that no less than in his time, physics in the 1960's is still supported both by evidence and by faith—by faith in the interconnectedness of the parts of nature; by faith in the intelligibility of nature; by faith in its simplicity, in its uniformity, and in its symmetry.

Intelligibility, simplicity, and uniformity of nature are concepts that are rarely reflected upon. They are like the air we breathe, they are taken for granted. All too often they are treated as self-evident notions that need no further scrutiny. Yet, when scrutinized with no reference to the scientist's faith in them, what remains of them? In a positivist framework of explanation they are reduced to formulas of convenience devoid of that absolute certainty with which the scientist espouses them. For once the principles of positivism are consistently applied, one cannot even have absolute certainty about one's own existence. Or as H. Reichenbach, a leading positivist philosopher of science, claimed: "We have no absolutely conclusive evidence that there is a physical world, and we have no absolutely conclusive evidence either that we exist."[30]

A long comment could be made about such a position, but let me confine myself to the most obvious. Whatever the validity of Reichenbach's claim, the scientist needs in his work an unconditional and complete trust or conviction in his own existence, in the existence of nature, and in its simplicity, orderliness, and intelligibility. On such points, the scientist can entertain no misgivings, no futile sophistry, no wholesale doubts, no endless questioning. The scientist must go beyond the set of evidences available to him and must assert that nature in its ultimate foundations is absolutely simple and perfectly ordered.

Of course the scientist's evidence of the simplicity and orderliness of nature is much more extensive than that available to the ordinary layman. Yet, even the scientist's glimpse of that orderliness is far from being exhaustive. The condition of the scientist is therefore much the same as that of the man of religion. Religious faith, like the faith of the scientist, has its set of evidences. Religious faith is not a blind faith.[31] Yet, numerous as its evidences might be, they do not form a complete, exhaustive set. Those evidences, like the evidences of science, are rather a prompting toward espousing propositions that imply unconditional affirmation and absolute commitment. It is through such commitment that the man of science grasps the simplicity and order of nature, and it is through a similar commitment that the man of religion grasps the spiritual and moral dimensions.[32]

Conclusion

This short outline of the analogy between scientific and religious faith was not prompted by some hidden aim of proselytizing. The meaning and purpose of the analogy is far deeper. It is my conviction that the recognition of that analogy is of paramount importance if a major tragedy of our culture is to be overcome. That tragedy is the split of our culture in two sections. Today, intellectuals are clustered in two camps; they are either humanists or scientists. They speak different languages, they hardly communicate with each other, and consider each other's problems as largely irrelevant.

Much has been said about that cultural split, and well before C. P. Snow came up with the now famous phrase, "two cultures." The tremendous response given to his work, *The Two Cultures,* is in itself evidence that the cultural split is a reality and a dangerous one. For that split, Snow laid much of the blame at the door of the humanists. It was in line with this that Snow prescribed his medicine for the restoration of the cultural unity. The medicine consisted in compulsory science courses, and a fair number of them to be imposed on students of humanities. I would not dispute that today students of humanities should do their best to become very familiar with science. Yet, just as important as the science one knows is one's familiarity with the foundations of the scientific quest. A careful study of those foundations will show that the sciences and the humanities have at their bases some remarkably common mental attitudes. One of them, and possibly the foremost, is the attitude of faith.

I know that the word "faith" is loaded with too many connotations to be readily acceptable to many. If so, I am not reluctant to look for a substitute expression. To me, a most appealing one was coined by none other than David Hume, hardly a friend of intellectual faith. He preferred to speak of faith as a "kind of firm and solid feeling." Regardless of Hume's philosophical outlook, I find the expression to be one that perfectly suits our purpose here. A full recovery of that "firm and solid feeling" by today's intellectuals would greatly help to forestall the threat posed to human values by an unbridled technologization of life. Today the evaluation of man is shifting more and more toward the quantitative aspects. Calipers, slide rules, statistics, and computers are being used in areas where they can never come even remotely close to the heart of the matter. For numbers, equations, and tools, however precise, can never touch on the very core of man and on his faith or, if you wish, on his strong and firm feelings. Computers may be said to do thinking, but only man feels in the sense of having faith. Therein lies man's basic dignity and also his most perennial need. The scientist is no exception to that rule. As this lecture tried to intimate, the man of science, like all his fellowmen, lives by faith and ultimately makes his progress in virtue of his faith.

NOTES

1. William James, *The Will To Believe and Other Essays in Popular Philosophy* (New York: Longmans, Green & Co., 1897), p. 1.

2. *Ibid.*, p. x.

3. *Ibid.*

4. The role of faith in scientific inquiry is rich in aspects, some of which have been given illuminating treatment in recent literature. Foremost to mention is the work by M. Polanyi, *Science, Faith and Society* (London: Oxford University Press, 1946; reprinted with a new Introduction by the author: University of Chicago Press, 1964). Some valuable contributions to the subject were made by noted physicists, such as H. Margenau, *Open Vistas: Philosophical Perspectives of Modern Science* (New Haven, Conn.: Yale University Press, 1961), pp. 73–76; K. Lonsdale, *I Believe: The Eighteenth Arthur Stanley Eddington Memorial Lecture, 6 November 1964* (Cambridge: University Press, 1964); H. K. Schilling, *Science and Religion: An Interpretation of Two Communities* (New York: Charles Scribner's Sons, 1962).

5. T. H. Huxley, "On the Advisableness of Improving Natural Knowledge," in *Method and Results: Essays* (New York: D. Appleton & Co., 1894), p. 40.

6. See Lord Kelvin's presidential address in *Report of the Forty-first Meeting of the British Association for the Advancement of Science* (held at Edinburgh in August, 1871) (London: John Murray, 1872), p. xciii.

7. Oliver Lodge, *Modern Views of Electricity* (London, 1889), pp. 382–83.

8. Max Planck, *Where Is Science Going?* translated by J. Murphy (New York: W. W. Norton & Co., 1932), p. 214.

9. Albert Einstein, "Clerk Maxwell's Influence on the Development of the Conception of Physical Reality" (1931), in *The World as I See It* (New York: Covici, 1934), p. 60.

10. Albert Einstein and Leopold Infeld, *The Evolution of Physics* (New York: Simon, 1938), pp. 312–13.

11. Albert Einstein, "Address to the Conference on Science, Philosophy, and Religion" (1940), in *Out of My Later Years* (New York: Philosophical Library, 1950), p. 26.
12. A. S. Eddington, *Science and the Unseen World: Swarthmore Lecture, 1929* (New York: Macmillan Co., 1930), pp. 73–74.
13. W. Heisenberg, "A Scientist's Case for the Classics," *Harper's Magazine*, CCXVI (May, 1958), p. 29.
14. Willem De Sitter, *Kosmos* (Cambridge, Mass.: Harvard University Press, 1932), p. 10.
15. L. Brillouin, *Scientific Uncertainty, and Information* (New York: Academic Press, 1964), p. 41.
16. On Wheeler's lecture, see W. Sullivan's report in the *New York Times*, February 5, 1967, sec. E, p. 5, cols. 3–5.
17. Robert Oppenheimer, *The Constitution of Matter* (Eugene: Oregon State System of Higher Education, 1956), p. 37.
18. R. A. Millikan, *Science and the New Civilization* (New York: Charles Scribner's Sons, 1930), p. 164.
19. On this point, see my work, *The Relevance of Physics* (Chicago: University of Chicago Press, 1966), pp. 479–80.
20. Erwin Schrödinger, *My View of the World*, translated by C. Hastings (Cambridge: University Press, 1964), pp. 3–4.
21. Einstein, in a letter of April 23, 1953, to Mr. J. E. Switzer; see D. J. de Solla Price, *Science since Babylon* (New Haven, Conn.: Yale University Press, 1961), p. 15.
22. Alfred N. Whitehead, *Science and the Modern World* (New York: Macmillan Co., 1926), pp. 18–19. For a very valuable discussion of the import of the Christian doctrine of creation, see L. Gilkey, *Maker of Heaven and Earth: The Christian Doctrine of Creation in the Light of Modern Knowledge* (1959), (Doubleday Anchor Book reprint; Garden City, N.Y.: Doubleday & Co., 1965). Concerning the Christian origins of modern science, Gilkey's discussion needs updating. Modern historical research has clearly shown those origins to be medieval, a point that was ignored by Gilkey's principal source on this point, several articles by M. Foster, published in *Mind* between 1934 and 1936.
23. Bacon, *Of the Dignity and Advancement of Learning*, Book 3, chap. iv, in *The Works of Francis Bacon*, edited by J. Spedding, R. L. Ellis, and D. D. Heath (new ed.; London, 1870), IV, 365.
24. On the impotence of the organismic concept of the physical world, see my *Relevance of Physics* (n. 19 above), chap. i.
25. J. Needham, *Science and Civilization in China, II.: History of Scientific Thought* (Cambridge: University Press, 1956), p. 581.
26. Galileo, *Dialogue concerning the Two Chief World Systems*, translated by Stillman Drake (Berkeley: University of California Press, 1953), p. 328.
27. Max Planck, *Where Is Science Going?* (n. 8 above), p. 214; see also his *The Philosophy of Physics*, translated by W. H. Johnston (New York: W. W. Norton & Co., 1936), pp. 122–23.
28. For a convenient source on these statements of Faraday, see H. Bence-Jones, *The Life and Letters of Faraday* (Philadelphia: J. B. Lippincott Co., 1870), II, 253, 417, 388.
29. It formed part of a program sponsored by the Gravity Research Foundation that for a number of years has awarded prizes to outstanding essays on various aspects of the problem of gravity.
30. H. Reichenbach, *The Rise of Scientific Philosophy* (Berkeley: University of California Press, 1951), p. 268.
31. Thus N. Wiener took pains to emphasize that the faith needed in scientific work has nothing in common with religious faith which he described as a set of

dogmas imposed from outside (*The Human Use of Human Beings* [reprinted by Doubleday & Co., n.d.], p. 193). Religious faith was therefore rejected by Wiener as "no faith." Such high-handed, if not superficial, handling of the concept of religious faith proves only one thing. A scientist, however eminent, may easily dispense, when discussing topics outside his field, with the elementary scientific duty of securing for himself a fair measure of proper information in the matter.

32. There are, of course, differences between the attitudes of faith as acted out within the religious and the scientific framework, respectively. Those differences mainly derive from the role played by revelation and authority as normative factors within the community of the faithful. The rise and growing influence of science was most beneficial in reminding theologians and churchmen that those normative factors are restricted to moral and supernatural considerations and can never play a heuristic role in man's search for the regularities of the processes of nature.