REVIEW

Evolution in Science and Religion. Robert Andrews Millikan. (New Haven: Yale University Press, 1927).

This book is divided into three parts, each being one of a series of Terry Lectures at Yale for 1927. The opening chapter, "The Evolution of Twentieth Century Physics," discusses eight empirical results the explanation of which leads to a distinctively different conceptual approach to the physical universe in the twentieth century from that held in the nineteenth century. These results are: 1) The unification of the electromagnetic spectrum to include radio waves, light, and radiant heat, 2) The discovery of x-rays and their instrumental use, 3) The discovery of radioactivity leading to the concept of the transmutation of the elements, 4) The formula $E = mc^2$, 5) Quantization in the photoelectric effect, 6) Quantization in spectroscopy, 7) The apparent independence of spectroscopic frequencies from anything structural in the atom, and finally 8) The quantization of angular momenta.

He might have added the wave nature of particles; and if he had written 25 years later he would have referred to the discovery of the mesons and "strange particles." But already by 1927 "modern" physics as distinct from "classical" physics was well established. And so for his purpose another 25 years of experience in empirical physics would have added little. The "revolution" of modern physics was well under way by 1927, although the so-called "atom-smashing" techniques, the discoveries of the neutron, of fission, and fusion, among other things, were to follow, each with its own startling revelation concerning the possible structure of nature. These are all a part of "modern" physics. After 1927 no thought was given to seeking explanations in terms of nineteenth century thought.

With this physical knowledge as a background, Millikan proceeded to Lecture II, "New Truth and Old." What is it that distinguishes what is new from what is old? The example of Galileo as contrasted with Aristotle is given. It may be asserted that Aristotle taught that "the natural state" of bodies is rest, but that later Galileo taught that the natural state is rest or motion in a straight line. This of course oversimplifies the position of each, but it serves to contrast the old as represented by Aristotle against the new as represented by Galileo.

But this is not the important difference between Aristotle and Galileo. More important is the way in which experiment was regarded. Millikan points out that Thales of Miletus, 600 B.C., "had done experimenting on amber"; Archimedes of Syracuse "by a flash of intuition which we moderns call a 'hunch' had discovered, about 225 B.C., a great hydrostatic law while he was in his bathtub"; Aristotle of Athens "had lauded the experimental method." But we must recognize that these experiments were isolated incidents, not only in history but also within the lives of the great men Thales, Archimedes, and Aristotle.

What was new with Galileo was that he made it his lifelong task to conduct a series of carefully planned experiments. This was his new contribution. That a natural state of a body could be motion in a straight line, important as it was to the future of physics, was a by-product of a method that was the most important new thing.

Thus grew a motivation for great minds to use the experimental method. This created a new tradition that can be traced through history by following the work of such people as Franklin, Faraday, Pasteur, and Darwin. And so, as Millikan says, the "escape into monasteries" became supplanted by a life of "service to humanity."

Because of the results of such planned experiments, the main contribution of this new science, a tradition began which continues to this day. Certain scientific results have become accepted as true although subsequent experiment showed them to be limited in application to a certain area. For example Galileo introduced into physics what is called kinematics. This added to the Greek contribution, largely through Archimedes, of statics. The motion of the pendulum, of falling bodies, and of bodies sliding down inclined planes could be represented mathematically as a result of Galileo's experiments. It remained for Newton to extend mechanics in an explicit manner to mathematical relations involving the masses of bodies. This branch of mechanics is known as dynamics.

A typical mathematical relation of Archimedes is illustrated by the teeter-totter. That is, the weight of A multiplied by his distance from the fulcrum is equal to the product of the weight of B by his distance from the fulcrum if balance exists. Notice that time does not enter and that weight is a force. Such is the nature of the formulae of statics. They involve forces and distances only.

A typical formula of kinematics is $s = \frac{1}{2} gt^2$, the well-known relation for falling bodies. In it s stands for the distance through which a body falls in time t when allowed to fall freely from an initial state of rest. Note that in this formula there are only distance and time. Kinematic formulae may also include rates and accelerations, but not force or mass.

The fundamental formula of Newton's dynamics is $F = ma$, where F stands for force and m for mass and a for acceleration. An important application of this formula is its use to distinguish between weight and mass. If the weight of a body be represented by w, then the force acting upon it when it is falling freely is this weight. The acceleration is a constant represented by g. Thus the formula $F = ma$ can be rewritten for this special case $W = mg$. Consequently the relation between mass units and weight units is thus given. For example in the English system of units the acceleration due to gravity is 32 ft. per second per second. Hence the mass of a one-pound weight is $\frac{1}{32}$ of a pound. It is called a slug.

These elementary examples from statics, kinematics, and dynamics continue to this day to be as true as when first stated by Archimedes, Galileo, and Newton, respectively—even though relativity has superseded Newtonian mechanics for more general applications in the universe. This is a characteristic of scientific development. Each period of time has given to man certain permanent knowledges—true on a certain plane, yet not true on a more universal plane of application. In order to illustrate this last it would be necessary to go fully into one of the new experimental results given by Millikan in his first lecture. What does Millikan say of the older ideas?

> . . . how about the framework of theory which held these facts together, [giving] them unity, assisting the memory in retaining them and in giving them relations? Is this all a lie? Emphatically no. (pp. 50–51)

As an example he says,

> The seventy-odd elements of chemistry, now become ninety-two [remember he wrote in 1927], are still and always will be the ultimate units of chemical combination, which was the only field in which their ultimateness had been tested before 1895. (p. 51)

Now, *i.e.*, again in 1927, Millikan can point out,

> . . . the physicist has discovered a new field, entered by new physical processes—X-ray processes, radioactive processes, cathode ray processes, in which the ultimateness of the elements disappears. (p. 51)

In order to illustrate what Millikan might have had in mind we note that common table salt is still NaCl just as it was seventy years ago in the eighteen hundreds. But since then physical science has examined the ultimate nature of atomic sodium, Na, for example. X-rays tell us something about its tightly bound electrons; cathode ray processes (*i.e.*, the study of electron streams) tell us about those electrons that can be dislodged from the atom; and radioactive processes tell us about the various sodium isotopes, that is, something about the nucleus.

Millikan says,

> The principle or theory of the conservation of mass, instead of being fit only for the scrap heap, still holds in all the experimental fields to which we had access when it was set up. We have found it failing only when quite recently we began to be able to investigate bodies moving close to the speed of light. What we have found is merely that the principle is not of as *universal* validity as we thought it was. (pp. 51–52)

Lecture III divides what Millikan calls "The Evolution of Religion" into four periods: 1. That period associated with primitive tribes. 2. That period when awakening begins and there is rebellion against human sacrifice. This period begins with Abraham in the Old Testament and continues through the life of Jesus on earth for some thousand years. 3. The third period begins about the time of Galileo when man's knowledge of nature is deepened, and hence also his conception of God. 4. The final stage—the one we are now in—is marked by man's realization that he himself is playing a part in the evolutionary process.

What does Millikan mean by religion? It consists of two groups of ideas. The first deals "with one's conception of the meaning of existence, of what is behind [the] various phenomena of life, coördinating them and giving unity and significance to nature—in a single word, with his conception of God" (pp. 71–72). The second group of ideas essential to religion has to do with man's realization of his own responsibility in this world.

These two ideas have always been associated in all religions, namely, ideas about the nature of God and definite notions about duty and responsibility. But notice how these *conceptions* of *God* and of *duty* change as man learns more and more and gets farther and farther away from the earliest stages of his development. (p. 72)

In treating of the primitive stage Millikan repeats the oft-quoted references to the "animistic" and "anthropomorphic" conceptions of God. He is cast in man's image. Even His senses are as man's, for after "God spoke to Abraham" the animal sacrifices continue, and even human suffering through flogging to propitiate God.

In the second stage beginning with Abraham and through Mohammed, through Buddha, and through Jesus a mortal blow was struck at "all childish literalisms, . . ." God now was no longer merely "a powerful human being, but a being whose qualities transcended all human qualities" (pp. 73–74). Man's conception of duty was embodied in the Golden Rule rather than in sacrifices. Thus the concept of God became such that

His gospel was simply the gospel of a beneficent creator whose most outstanding attribute was love, and that conception of course made love, unselfishness, the first duty of man. (p. 74)

Millikan does not overlook the backsliding of the religions during the next thousand years; nevertheless the above two concepts were a basis for religions in the western world.

The third stage begins with Galileo. Millikan quotes Galileo as if he says to himself, "I will try by careful experiments to see whether it is correct or incorrect." Thus planned experimentation with nature becomes the way leading to truth. With this new source of truth is associated a new concept of duty. Whereas the monasteries of the middle ages testify to the old conception of God and of duty, now a new tradition is begun that is carried through by a Newton, a Maxwell, a Pasteur, or a Kelvin. "The new God was the God of law and order, the new duty to know that order, and to get into harmony with it" (p. 80).

From this stage Millikan goes to the fourth stage wherein man first comes to recognize evolution through the rocks, radioactivity, etc., and by minute studies of comparative anatomies. The final level of this development is arrived at when man recognizes in a self-conscious way his own part in this process—and furthermore this process is "progress."

In this sense the idea that nature is at bottom benevolent has now become well nigh universal. It is a contribution of science to religion, and a powerful extension or modification of the idea that Jesus had seen so clearly and preached so persistently. (p. 82)

Millikan has much more to say along this line. One of the more important contributions is his condemnation with almost equal emphasis of both fundamentalism and atheism—neither of which is rational. There is a word about humility:

Physics, however, has recently learned its lesson, and it has at the present moment something to teach to both philosophy and religion, namely, the lesson of not taking itself too seriously, not imagining that the human mind yet understands, or has made more than the barest beginnings toward understanding the universe. Today physics is much more open-minded, much less dogmatic, much less disposed to make all-inclusive generalizations, and to imagine that it is dealing with ultimate verities, than it was twenty-five years ago. (p. 93)

If there is anything that is calculated to impart an attitude of humility, to keep one receptive of new truth and conscious of the limitations of our understanding, it is a bit of familiarity with the growth of modern physics. (p. 94)

Millikan concludes after asking "Can man with searching find out God?":

The prophet Micah said, twenty-five hundred years ago, "What doth the Lord require of thee but to do justice, to love mercy, and to walk humbly with thy God?" Modern science, of the real sort, is slowly learning to walk humbly with its God, and in learning that lesson it is contributing something to religion. (p. 94–95)

This is hardly a review in the sense that it suggests to the reader to read or not to read a certain book—for as noted the book was written 37 years ago. To the reading public of this century this is a long time indeed. And yet as has been mentioned, by 1927 "modern" physics as understood in the twentieth century was already well on the way to its present stage of development because of the results of experimental ideas as recited by Millikan.

What are the concepts suggested in the book that are of special interest to readers of this journal?

1. Though Millikan does not say anything about what we call discrete degrees, there is in his second lecture support for this concept. Science finds on a certain plane of application certain

laws. These laws may remain truths on that plane even if investigation into other levels indicates that more general laws are valid. It may happen that the earlier laws can with certain adjustments be regarded as special cases of the new more general laws. For example the Newtonian laws of mechanics are a special case of special relativity when the ratio of the velocity of a body to that of light is very small. As an example of this, when Millikan performed his famous oil-drop experiment measuring the electric charge on an electron, he could ignore relativity. This was for the reason that the velocity of his oil droplets was very small indeed. Later investigators designing acceleration apparatus for electrons could not ignore relativity, and so the design of such apparatus must incorporate physical allowance for the change of mass of high speed particles. And again the chemist analyzing the products and energy exchange in the process of lighting a match can ignore $E = mc^2$, but the physicist cannot when considering nuclear processes.

Nevertheless there is something essentially new about these later theories in the demand they make upon the mind to think of levels of creation beyond those imagined before 1900—which classical physics was designed to explain.

2. A second important idea introduced by Millikan is his support of truth on various planes. This was not only to support the cosmological importance of the existence of those planes but to support the idea of truth itself. On page 51, he asks concerning the older ideas of mechanics coming to us from Archimedes, Galileo, and Newton, in the light of twentieth century physics, "Is this all a lie?" And he answers "Emphatically no." This is an important point. Many today are impressed with certain superficial aspects of history that place emphasis upon change, what is old, etc. Many go so far as to perform a play upon the term "relativity" coming up with an extrapolation far beyond the intent of Einstein. Thus we are plagued with a philosophy of relativism. If our father's ideas must be changed, so will ours. So there is no absolute, no truth. But Millikan believed in absolutes—and he saw a justification for limiting the application of law to the plane for which it was designed. The danger to a law comes when its application is made to planes beyond that for which it was so designed.

Let it be repeated that there are two important points so far recited. First, that there exist planes (or as we would say, degrees) in nature. This is a matter of our knowledge of the structure of matter and is cosmological in nature. Second, by granting this structure we adopt a completely new way of thinking about the universe as distinct from that possible under a materialistic—monistic cosmology.

3. For some of our readers the title *Evolution in Science and Religion* may have led to a disappointment in their reading of this review because little has been said about religion as they know it. And yet Millikan was a religious man in the meaning of that term to many people today. There are still the remnants with many of some idea of a "First Cause." With others religion is associated with immensity or variety in the universe—what might be called a "cosmic religion." With some there is a strong belief in man, in the altruistic implications derived from a study of the life of Christ on earth, and of a belief in the evolution of mankind toward better things. Not only is there a written revelation for such people, but there is also a revelation to man through science. Millikan had these beliefs at least.

The strong belief in a personal God possessing the attributes of Divine love and Divine wisdom is peculiar to the New Church—or to people who follow Swedenborg. We do not find this in the writings of others—nor should we expect to do so. Nevertheless the belief in altruism can be directed toward a life of use and charity, and a belief in a lawful universe can lead one to philosophical principles based upon a belief in a First Cause. These seem to be the basis upon which many a modern can enter into the good life.

4. Millikan's belief expressed thirty-seven years ago that science makes a contribution to religion does not seem to have been borne out to any noticeable extent in succeeding years. Although religion seems to have departed considerably from open support of the fundamentalist position, it can well be questioned whether it has benefited to any noticeable extent from science in gaining a deeper concept of God. Also, even if it was true in 1927 that "the idea that nature is at bottom benevolent has now become well nigh universal" there is evidence that this idea is not universally accepted today. A certain pessimism seems to be manifest among those who survey our present scene. If science has placed in the

hands of mankind powerful instruments for natural good, it has likewise discovered that these ultimates have an equal power for evil. Thus the responsibility shifts back to man as to which of these powers will be used. It can be questioned whether there is at this time a faith in the benevolence of nature. Is there not rather a fear for how man will use the otherwise neutral powers of nature now known to him?

5. Some of our readers might question Millikan's view that Galileo's scientific method was of a religious nature. Even if one denies the religious nature, one cannot deny that the scientific mode of thought became and is now a ruling mode of thought. Therefore it seems that we have three possibilities. First, that the scientific method is religious in nature as Millikan states, or second, that it takes the place of religion, or third, that its effects either support or challenge religion. Evidently there are people who believe that each of these alternates is true.

6. I would like to ask a question about Millikan's anthropological conclusions as to man's early state on the earth based upon examination of the customs of so-called "primitive" tribes living today. Are these primitives the same as the historical primitives? Are we to assume, or has it been proved, that the modern primitive tribes in all the years of man's existence on this earth have not suffered any changes as did the so-called civilized tribes?