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A MEMO TO OUR READERS:

On a Sunday morning two years ago, a staff member of THINK flicked on the radio and, by chance, tuned in on a provocative discussion. Dr. Charles H. Townes, the distinguished scientist, was talking with a Bible class. The subject was the relationship of science to religion, and Dr. Townes was urging that scientific and religious thought, far from conflicting, are today finding more and more in common and are destined ultimately to merge.

We were so intrigued by Dr. Townes's ideas that we asked him if he would develop them in an article for THINK. He said he would consider it, but the path from that Sunday discussion to an article proved more tortuous than either Dr. Townes or THINK anticipated.

Dr. Townes rewrote his talk and was still dissatisfied with it when word came from Stockholm that he had been awarded a Nobel Prize in physics for his work in developing the maser.

The trip to Stockholm and subsequent demands delayed his return to the manuscript. Then he felt, as did we, that publication so soon after the international recognition might be misunderstood.

It was not until last winter that Dr. Townes again returned to his manuscript on science and religion. In rewriting it, he brought a force and clarity to his ideas which, we feel, fully justified the slow maturation.

The article, "The Convergence of Science and Religion," begins on page 2.

— The Editors

The author, a scientist and an active church member, explains why he believes that science and religion may ultimately converge. Dr. Townes, whose work on the maser won him a Nobel Prize in 1964, is Provost and Professor of Physics at MIT.

The Convergence of Science and Religion

by Charles H. Townes

THE EVER-INCREASING SUCCESS of science has posed many challenges and conflicts for religion — conflicts which are resolved in individual lives in a variety of ways. Some accept both religion and science as dealing with quite different matters by different methods, and thus separate them so widely in their thinking that no direct confrontation is possible. Some repair rather completely to the camp of science or of religion and regard the other as ultimately of little importance, if not downright harmful.

To me science and religion are both universal, and basically very similar. In fact, to make the argument clear, I should like to adopt the rather extreme point of view that their differences are largely superficial, and that the two become almost indistinguishable if we look at the real nature of each. It is perhaps science whose real nature is the less obvious, because of its blinding superficial successes. To explain this, and to give perspective to the non-scientists, we must consider a bit of the history and development of science.

The march of science during the 19th century produced enormous confidence in its success and generality. One field after another fell before the objective inquiry, experimental approach, and the logic of science. Scientific laws appeared to take on an absolute quality, and it was very easy to be convinced that science in time would explain everything.

This was the time when Laplace could believe that if he knew the position and velocity of every particle in the universe, and could calculate sufficiently well, he would then know the entire future. Laplace was simply expressing the evident experience of the time, that the success and precision of scientific laws had changed determinism from a speculative argument to one which seemed inescapable.

This was the time when the devout Pasteur, asked how he as a scientist could be religious, simply replied that his laboratory was one realm, and that his home and religion were a completely different one.

Scientific Absolutism

There are today many vestiges of this 19th-century scientific absolutism in our thinking and attitudes. It has given Communism, based on Marx's 19th century background, some of its sense of the inexorable course of history and of "scientific" planning of society.

Towards the end of the 19th century, many physical scientists viewed their work as almost complete and needing only some extension and more detailed refinement. But soon after, deep problems began to appear. The world seems relatively unaware of how deep these problems really were, and of the extent to which some of the most fundamental scientific ideas have been overturned by them. Perhaps this unawareness is because science has been vigorous in changing itself and continuing to press, and has also diverted attention by ever more successes in solving the practical problems of life.

Many of the philosophical and conceptional bases of science have in fact been disturbed and revolutionized. The poignancy of these changes can be grasped only through sampling them. For example, the question whether light consists of small particles shot out by light sources or wave disturbances originated by them had been debated for some time by the great figures of science. The question was finally settled in the early 19th century by brilliant experimentation which could be thoroughly interpreted by theory. The experiments told scientists of the time that light was unequivocally a wave and not particles. But about 1900, other experiments turned up which showed just as unequivocally that light is a stream of particles rather than waves. Thus physicists were presented with a deeply disturbing paradox. Its solution took several decades, and was only accomplished in the mid-1920s by the development of a new set of ideas known as quantum mechanics.

The trouble was that scientists were thinking in terms of their common everyday experience and that experience encompassed the behavior of large objects, but not yet many atomic phenomena. Examination of light or atoms in detail brings us into a new realm of very small quantities with which we have had no previous experience, and where our intuitions could well be untrustworthy. And now in retrospect, it is not at all surprising that the study of matter on the atomic scale has taught us new things, and that some are inconsistent with ideas which previously had seemed so clear.

Physicists today believe that light is neither precisely a wave nor a particle but both, and we were mis-

Einstein and Job. Faith is necessary to men of both science and religion, says Dr. Townes. A firm belief in an orderly universe, somewhat like Job's durable conviction, sustained Albert Einstein. "God is very subtle," Einstein once remarked, "but he is not malicious."

taken in even asking the question, "Is light a particle or is it a wave?" It can display both properties. So can all matter, including baseballs and locomotives. We don't ordinarily observe this duality in large objects because they do not show wave properties prominently. But in principle we believe they are there.

We have come to believe other strange phenomena as well. Suppose an electron is put in a long box where it may travel back and forth. Physical theory now tells us that, under certain conditions, the electron will be sometimes found towards one end of the box and sometimes towards the other, but never in the middle. This statement clashes absurdly with ideas of an electron moving back and forth, and yet most physicists today are quite convinced of its validity, and can demonstrate its essential truth in the laboratory.

The Uncertainty Principle

Another strange aspect of the new quantum mechanics is called the uncertainty principle. This principle shows that if we try to say exactly where a particle (or object) is, we cannot say exactly how fast it is going and in what direction, all at the same time; or, if we determine its velocity, we can never say exactly what its position is. And so, according to this theory, Laplace was wrong from the beginning. If he were alive today, he would probably understand along with other contemporary physicists that it is fundamentally impossible to obtain the information necessary for his precise predictions, even if he were dealing with only one single particle, rather than the entire universe.

The modern laws of science seem, then, to have turned our thinking away from complete determinism and towards a world where chance plays a major role. It is chance on an atomic scale, but there are situations and times when the random change in position of one atom or one electron can materially affect the large-scale affairs of life and, in fact, our entire society. A striking example involves Queen Victoria who, through one such event on an atomic scale, became a mutant and passed on to certain male descendants in Europe's royal families the trait of hemophilia. Thus one unpredictable event on an atomic scale had its effect on both the Spanish royal family and, through an afflicted czarevitch, on the stability of the Russian throne.

Einstein and Chance

This new view of a world which is not predictable from physical laws was not at all easy for physicists of the older tradition to accept. Even Einstein, one of the architects of quantum mechanics, never completely accepted the indeterminism of chance which it implies. This is the origin of his intuitive response, *"Herr Gott würfelt nicht"* — the Lord God doesn't throw dice! It is interesting to note also that Russian Communism, with its roots in 19th century determinism, for a long time took a strong doctrinaire position against the new physics of quantum mechanics.

When scientists pressed on to examine still other realms outside our common experience, further surprises were found. For objects of much higher velocities than we ordinarily experience, relativity shows that very strange things happen. First, objects can never go faster than a certain speed, regardless of how hard they are pushed. Their absolute maximum speed is that of light — 186,000 miles per second. Further, when objects are going fast, they become shorter and more massive — they change shape and also weigh more. Even time moves at a different rate; if we send a clock off at a high velocity, it runs slower.

The Cat-Kitten Concept

This peculiar behavior of time is the origin of the famous cat-kitten conceptual experiment. Take a litter of six kittens and divide them into two groups. Keep three of them on earth, send the other three off in a rocket at a speed nearly as fast as light, and after one year bring them back. The earth kittens will obviously have become cats, but the ones sent into space will have remained kittens. This theory has not been tested with kittens, but it has been checked experimentally with the aging of inanimate objects and seems to be quite correct. Today the vast majority of scientists believe it true.

How wrong, oh how wrong were many ideas which physicists felt were so obvious and well-substantiated at the turn of the century!

Scientists have now become a good deal more cautious and modest about extending scientific ideas into realms where they have not yet been thoroughly tested. Of course, an important part of the game of science is in fact the development of general laws that can be extended into new realms. These laws are often remarkably successful in telling us new things or in predicting things which we have not yet directly observed. And yet we must always be aware that such extensions may be wrong, and wrong in very fundamental ways. In spite of all the changes in our views, it is reassuring to note that the laws of 19th century science were not so far wrong in the realm in which they were initially applied — that of ordinary velocities and of objects larger than the point of a pin. In this realm they were essentially right, and we still teach the laws of Newton or of Maxwell, because in their own important sphere they are valid and useful.

We know today that the most sophisticated present scientific theories, including modern quantum mechanics, are still incomplete. We use them because in certain areas they are so amazingly right. Yet they lead us at times into inconsistencies which we do not understand, and where we must recognize that we have missed some crucial ideas. We simply admit and accept the paradoxes and hope that sometime in the future they will be resolved by a more complete understanding. In fact, by recognizing these paradoxes clearly and studying them, we can perhaps best understand the limitations in our thinking and correct them.

With this background on the real state of scientific understanding, we come now to the similarity and near identity of science and religion. The goal of science is to discover the order in the universe, and to understand through it the things we sense around us, and even man himself. This order we express as scientific principles or laws, striving to state them in the simplest and yet most inclusive ways. The goal of religion may be stated, I believe, as an understanding (and hence acceptance) of the purpose and meaning of our universe and how we fit into it. Most religions see a unifying and inclusive origin of meaning, and this supreme purposeful force we call God.

Understanding the *order* in the universe and understanding the *purpose* in the universe are not identical, but they are also not very far apart. It is interesting that the Japanese word for physics is *butsuri,* which translated means simply *the reasons for things*. Thus we readily and inevitably link closely together the nature and the purpose of our universe.

What are the aspects of religion and science which often make them seem almost diametrically opposite? Many of them come, I believe, out of differences in language used for historical reasons, and many from quantitative differences which are large enough that unconsciously we assume they are qualitative ones. Let us consider some of these aspects where science and religion may superficially look very different.

The Role of Faith

The essential role of faith in religion is so well known that taking things on faith rather than proving them is usually taken as characteristic of religion, and as distinguishing religion from science. But faith is essential to science too, although we do

not so generally recognize the basic need and nature of faith in science.

Faith is necessary for the scientist even to get started, and deep faith necessary for him to carry out his tougher tasks. Why? Because he must have confidence that there is order in the universe and that the human mind — in fact his own mind — has a good chance of understanding this order. Without this confidence, there would be little point in intense effort to try to understand a presumably disorderly or incomprehensible world. Such a world would take us back to the days of superstition, when man thought capricious forces manipulated his universe. In fact, it is just this faith in an orderly universe, understandable to man, which allowed the basic change from an age of superstition to an age of science, and has made possible our scientific progress.

The necessity of faith in science is reminiscent of the description of religious faith attributed to Constantine: "I believe so that I may know." But such faith is now so deeply rooted in the scientist that most of us never even stop to think that it is there at all.

Einstein affords a rather explicit example of faith in order, and many of his contributions come from intuitive devotion to a particularly appealing type of order. One of his famous remarks is inscribed in German in Fine Hall at Princeton: "God is very subtle, but he is not malicious." That is, the world which God has constructed may be very intricate and difficult for us to understand, but it is not arbitrary and illogical. Einstein spent the last half of his life looking for a unity between gravitational and electromagnetic fields. Many physicists feel that he was on the wrong track, and no one yet knows whether he made any substantial progress. But he had faith in a great vision of unity and order, and he worked intensively at it for thirty years or more. Einstein had to have the kind of dogged conviction that could have allowed him to say with Job, "Though he slay me, yet will I trust in him."

For lesser scientists, on lesser projects, there are frequent occasions when things just don't make sense and making order and understanding out of one's work seems almost hopeless. But still the scientist has faith that there is order to be found, and that either he or his colleagues will someday find it.

The Role of Revelation

Another common idea about the difference between science and religion is based on their methods of discovery. Religion's discoveries often come by great revelations. Scientific knowledge, in the popular mind, comes by logical deductions, or by the accumulation of data which is analyzed by established methods in order to draw generalizations called laws. But such a description of scientific discovery is a travesty on the real thing. Most of the important scientific discoveries come about very differently and are much more closely akin to revelation. The term itself is generally not used for scientific discovery, since we are in the habit of reserving revelation for the religious realm. In scientific circles one speaks of intuition, accidental discovery, or says simply that "he had a wonderful idea."

If we compare how great scientific ideas arrive, they look remarkably like religious revelation viewed in a non-mystical way.

Think of Moses in the desert, long troubled and wondering about the problem of saving the children of Israel, when suddenly he had a revelation by the burning bush.

Consider some of the revelations of the New Testament.

Think of Gautama Buddha who traveled and inquired for years in an effort to understand what was good, and then one day sat down quietly under a Bo tree where his great ideas were revealed.

Similarly, the scientist, after hard work and much emotional and intellectual commitment to a troubling problem, sometimes suddenly sees the answer. Such ideas much more often come during off-moments than while confronting data.

A striking and well-known example is the discovery of the benzene ring by Kékulé, who while musing at his fireside was led to the idea by a vision of snakes taking their tails in their mouths. We cannot yet describe the human process which leads to the creation of an important and substantially new scientific insight. But it is clear that the great scientific discoveries, the real leaps, do not usually come from the so-called "scientific method," but rather more as did Kékulé's — with perhaps less picturesque imagery, but by revelations which are just as real.

Another popular view of the difference between science and religion is based on the notion that religious ideas depend only on faith and revelation while science succeeds in actually proving its points. In this view, proofs give to scientific ideas a certain kind of absolutism and universalism which religious ideas have only in the claims of their proponents. But the actual nature of scientific "proof" is rather different from such simple ideas.

Proving a Set of Postulates

Mathematical or logical proof involves choice of some set of postulates, which hopefully are consistent with one another and which apply to a situation of interest. In the case of natural science, they are presumed to apply to the world around us. Next, on the basis of agreed-on laws of logic, which must be assumed, one can derive or "prove" the consequences of these sets of postulates.

How can we be sure the postulates are satisfactory? The mathematician Gödel has shown that, in the most generally used mathematics, it is fundamentally impossible to know whether or not the set of postulates chosen are even self-consistent. Only by constructing and using a new set of master postulates can we test the consistency of the first set. But these in turn may be logically inconsistent without the possibility of our knowing it. Thus we never have a real base from which we can reason with surety. Gödel doubled our surprises by showing that, in this same mathematical realm, there are always mathematical truths which fundamentally cannot be proved by the approach of normal logic. His important proofs came only about three decades ago, and have profoundly affected our view of human logic.

There is another way by which we become convinced that a scientific idea or postulate is valid. In the natural sciences, we "prove" it by making some kind of test of the postulate against experience. We devise experiments to test our working hypotheses, and believe those laws or hypotheses are correct which seem to agree with our experience. Such tests can disprove an hypothesis, or can give us useful confidence in its applicability and correctness, but never proof in any absolute sense.

Can religious beliefs also be viewed as working hypotheses, tested and validated by experience? To some this may seem a secular and even an abhorrent view. In any case, it discards absolutism in religion. But I see no reason why acceptance of religion on this basis should be objectionable. The validity of religious ideas must be and has been tested and judged through the ages by societies and by individual experience. Is there any great need for them to be more absolute than the law of gravity? The latter is a working hypothesis whose basis and permanency we do not know. But on our belief in it, as well as on many other complex scientific hypotheses, we risk our lives daily.

Science usually deals with problems which are so much simpler and situations which are so much more easily controllable than does religion that the quantitative difference in directness with which we can test hypotheses generally hides the logical similarities which are there. The controlled experiment on religious ideas is perhaps not possible at all, and we rely for evidence primarily on human history and personal experience. But certain aspects of natural science, and the extension of science into social sciences, have also required similar use of experience and observation in testing hypotheses instead of only easily reproducible experiments.

Suppose now that we were to accept completely the proposition that science and religion are essentially similar. Where does this leave us and where does it lead us? Religion can, I believe, profit from the experience of science where the hard facts of nature and the tangibility of evidence have beaten into our thinking some ideas which mankind has often resisted.

First, we must recognize the tentative nature of knowledge. Our present understanding of science or of religion is likely, if it agrees with experience, to continue to have an important degree of validity just as does Newtonian mechanics. But there may be many deeper things which we do not yet know and which, when discovered, may modify our thinking in very basic ways.

Expected Paradoxes

We must also expect paradoxes, and not be surprised or unduly troubled by them. We know of paradoxes in physics, such as that concerning the nature of light, which have been resolved by deeper understanding. We know of some which are still unresolved. In the realm of religion, we are troubled by the suffering around us and its apparent inconsistency with a God of love. Such paradoxes confronting science do not usually destroy our

faith in science. They simply remind us of a limited understanding, and at times provide a key to learning more.

Perhaps there will be in the realm of religion cases of the uncertainty principle, which we now know is such a characteristic phenomenon of physics. If it is fundamentally impossible to determine accurately both the position and velocity of a particle, it should not surprise us if similar limitations occur in other aspects of our experience. This opposition in the precise determination of two quantities is also referred to as complementarity; position and velocity represent complementary aspects of a particle, only one of which can be measured precisely at any one time.

Nils Bohr has already suggested that perception of man, or any living organism as a whole, and of his physical constitution represents this kind of complementarity. That is, the precise and close examination of the atomic makeup of man may of necessity blur our view of him as a living and spiritual being. In any case, there seems to be no justification for the dogmatic position taken by some that the remarkable phenomenon of individual human personality can be expressed completely in terms of the presently known laws of behavior of atoms and molecules. Justice and love may also represent such complementarity. A completely loving approach and the simultaneous meting out of exact justice hardly seem consistent.

These examples could be only somewhat fuzzy analogies of complementarity as it is known in science, or they may indeed be valid though still poorly defined occurrences of the uncertainty principle. But in any case, we should expect such occurrences and be forewarned by science that there will be fundamental limitations to our knowing everything at once with precision and consistency.

Converge They Must

Finally, if science and religion are so broadly similar, and not arbitrarily limited in their domain, they should at some time clearly converge. I believe this confluence is inevitable. For they both represent man's efforts to understand his universe and must ultimately be dealing with the same substance. As we understand more in each realm, the two must grow together. Perhaps by the time this convergence occurs, science will have been through a number of revolutions as striking as those which have occurred in the last century, and taken on a character not readily recognizable by scientists of today. Perhaps our religious understanding will also have seen progress and change. But converge they must, and through this should come new strength for both.

In the meantime, every today, with only tentative understanding and in the face of uncertainty and change, how can we live gloriously and act decisively? It is this problem, I suspect, which has so often tempted man to insist that he has final and ultimate truth locked in some particular phraseology or symbolism, even when the phraseology may mean a hundred different things to a hundred different people. How well we can commit our lives to ideas which we recognize in principle as only tentative represents a real test of mind and emotions.

Galileo espoused the cause of Copernicus' theory of the solar system, and at great personal cost because of the Church's opposition. We know today that the question on which Galileo took his stand, the correctness of the idea that the earth rotates around the sun rather than the sun around the earth, is largely an unnecessary question. The two descriptions are equivalent, according to general relativity, although the first is simpler. And yet we honor Galileo for his pioneering courage and determination in deciding what he really thought was right and speaking out. This was important to his own integrity and to the development of the scientific and religious views of the time, out of which has grown our present better understanding of the problems he faced.

The authority of religion seemed more crucial in Galileo's Italy than it usually does today, and science more fresh and simple. We tend to think of ourselves as now more sophisticated, and science and religion as both more complicated so that our position can be less clear-cut. Yet if we accept the assumption of either one, that truth exists, surely each of us should undertake the same kind of task as did Galileo, or long before him, Gautama. For ourselves and for mankind, we must use our best wisdom and instincts, the evidence of history and wisdom of the ages, the experience and revelations of our friends, saints and heroes in order to get as close as possible to truth and meaning. Furthermore, we must be willing to live and act on our conclusions. ●