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# LOGIC AND UNCERTAINTIES IN SCIENCE AND RELIGION*

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Science and religion represent two different aspects of human understanding and different instincts which often seem *quite* different, yet can be closely related. Science, with its experiments and logic, tries to understand the order or structure of the universe. Religion, with its theological inspiration and reflection, tries to understand the purpose or meaning of the universe. These two are cross-related. Purpose implies structure, and structure ought somehow to be interpretable in terms of purpose.

At least this is the way I see it. I am a physicist. I also consider myself a Christian. As I try to understand the nature of our universe in these two modes of thinking, I see many commonalities and crossovers between science and religion. It seems logical that in the long run the two will even converge

## *Can we Really Separate Science and Religion?*

For most of Western history science and religion were closely tied to one another. Theologians were intellectuals of their communities, and although science was more limited in scope it tended to be integrated with philosophy and theology. With the advent of experimental science during the Enlightenment, the practice of empirical research grew very rapidly and very successfully. Skirmishes between science and the Church signaled a change. Copernicus's heliocentric universe was condemned by the Roman Catholic Church in 1616 and Galileo was forbidden to defend it; Galileo's exoneration awaited Pope John Paul II just in recent times. By the nineteenth century open clashes between science and religion had become com-

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mon, notably with the battle between the theory of evolution and the seven day creation account in Genesis.

In our time it has become difficult for many to understand how one can put the scientific world view and the scientific method together with religion. Louis Pasteur, who was a very devout person, was asked the question: How can you be both a scientist and a person of faith? His answer went something like this: "Well, I do science in my laboratory. My home and my religion are separate." That was all he could say.

What Pasteur represents is a sort of two-language approach: Whereas science provides the language of laboratory understanding, religion provides a private language of faith which is needed in our relation to other humans. Such an attempted separation is not uncommon today. I would put Pope John Paul II in the two-language camp. While he honors science and recognizes its importance, he seems to adhere to the view that these are separate tracks of thought which should not tell each other what to think. Science and theology should cooperate with each other in the common pursuit of the welfare of humanity; but, the Pope believes, in the final analysis they cannot teach each other very much.

On this the Pontiff seems to be in tune with our wider culture – what some call our two cultures – wherein we split apart the humanities and the sciences. Our cultural sensibilities separate religion and other humanistic affections from science like we separate warm from cold, the poem from the microscope, the living from the dead. We sometimes even separate nature from science, assuming that nature is warm and that this warmth can be apprehended only by the poet. The scientist, in contrast, allegedly invokes cold-hearted methods that are as deadening to nature as they are to the human spirit. Take William Wordsworth, for example:

> Sweet is the lore which nature brings;
> Our meddling intellect
> Misshapes the beauteous forms of things
> We murder to dissect[1]

Or, John Keats:

> Do not all charms fly
> At the mere touch of cold philosophy?[2]

[1] "The Tables Turned" in *William Wordsworth: Selected Poetry,* ed. Mark van Doren (New York: The Modern Library, 1950), p. 83.

[2] "Sonnet to Science," in *John Keats: Poems,* ed. Gerald Bullett (London: J. M. Dent and Sons, 1974), p. 163.

Or, Edgar Allen Poe:

> Science, true daughter of Old Time thou art
> Who alterest all things with pondering eyes
> Why preyest thou thus upon the poet's heart
> Vulture, whose wings are dull realities.[3]

What these poets assume is a split between the aesthetic and the empirical, a rift between human affections and disciplined research. But a closer look will show that aesthetic affections are alive and well in the scientist. The vastness of the apparently limitless reaches of outer space combined with the intriguing complexities of the smallest microscopic things elicit an aesthetic response in the human soul. Nature communicates meaning; and science can actually facilitate this communication. Alexander Pope puts it this way:

> He who through vast immensity can pierce,
> See worlds on worlds compose one universe,
> Observe how system into system runs,
> What other planets circle other suns,
> What varied beings people every star,
> May tell why heav'n has made us as we are.[4]

Whether through the latest telescope, the microscope, or the landscape around us, we can see beauty in nature; and this beauty communicates meaning. Scientist Henri Poincaré testified to the aesthetic attractiveness of the twin facts of simplicity and immensity in nature. We seek out, he observed, the vast expanses of space and the microscopic particles of matter, in part because we take delight in them. Our aesthetic sensibilities are drawn to the vast and to the simple, the tiny and the remote.

Although science and religion are frequently separated and contrasted, I believe they can provide overlapping ways in which we apprehend the one universe of which we are a part. Nature gives voice to beauty, and beauty to meaning and purpose. The language of science may appear lifeless or deadening to some poets; but the scientist himself or herself is often sensitive to the beauty of nature, immensity of space, and the complexity of the material world.

Let us look at this again from a slightly different angle. The beauty of nature elicits a response from both our scientific and our poetic modes of understanding. Our aesthetic sensibility is triggered by our experience

[3] *The Complete Poems and Stories of Edgar Allen Poe*, texts established by Edward H. O'Neill (New York: Alfred A. Knopf, 1967), vol. 1, p. 28.

[4] Alexander Pope, "An Essay on Man," in *Alexander Pope's Opus Magnum, 1729-1744*, ed. Miriam Leranbaum (Oxford: Clarendon Press, 1977), p. 51.

with nature's beauty, and it comes to voice in both scientific and religious languages.

Note how beauty and truth seem to converge for both the poet John Keats and the physicist Werner Heisenberg. Keats said it this way: "Beauty is truth, and truth beauty."[5] Heisenberg argued that when nature leads us, by way of scientific analysis, to simple and beautiful mathematical forms, we are irresistibly impressed by the feeling that these forms must be "true"; that they must in fact reveal an actual feature of the natural world. We scientists, seeing a simple relationship that seems beautiful, intuitively think it likely to be true. Both scientists and theologians give themselves to the truth that transcends and invites us.

*Similarities in Logic and Uncertainty*

My own view is that science and religion are remarkably similar in spite of the great differences assigned them by our culture. They are remarkably similar, very simply because of who we are as people. It is people who author both science and religion. It is we who ask how to think about things and how to learn about things. We can expect similarities in approach to both science and religion because both emerge from the same human mind.

Science and religion not only share a common logic; they also share something else, namely, uncertainty. We must recognize that we do not know things for sure. Knowledge, even scientific knowledge, is less than absolute. As research proceeds we pick out a set of postulates which seem reasonable to us. We test those postulates with our experience or with experiments. We test to see what fits. Yet the postulates remain postulates. Some level of uncertainty regarding the validity of the postulates remains.

The mathematician Gödel proved that uncertainty is inherent even in the nature of our logic. Mathematics proceeds by employing a working set of assumptions and from these, using the rules of logic, proving something particular. Gödel proved that we can never be sure that the assumptions with which we started are even self-consistent, let alone true. The only way we may show that they are self-consistent is to appeal to a new set of assumptions, and from these try to prove the original set. But of course, this new set of assumptions is subject to the same uncertainty

[5] "Ode on a Grecian Urn," in *John Keats: Poems,* ed. Gerald Bullett (London: J. M. Dent and Sons, 1974), p. 192.

regarding self-consistency, and so on. Thus there will always be things which we assume to be true but which cannot be proved. Logic and uncertainty come together in a single package. And to take them seriously, there must be faith.

*Reason Builds on Faith, Even in Science*

Religion, with its theological reflection, builds on faith. Science too builds on faith. How? For successful science of the type we know, we must have faith that the universe is governed by reliable laws and, further, that these laws can be discovered by human inquiry. The logic of human inquiry is trustworthy only if nature is itself logical. Science operates with the faith that human logic can in the long run understand nature's laws and that they are dependable. This is the faith of reason.

Why would a scientist work day and night for a long period of time on a problem that is difficult to solve? For such motivation, he or she must have faith that the problem is solvable, and that there is an inherent logic in nature which his or her mind is capable of reading. Prior to solving a problem, the scientist works with faith in the as yet unseen reasonableness of nature.

Albert Einstein was such an example. For the final twenty years of his life he worked on a Unified Field Theory. As he worked, he reasoned that there had to be some form of a unified account of the laws of nature which warranted his effort to discover them, even though in the long run he did not achieve this goal. We scientists work on the basis of a fundamental assumption regarding reason in nature and reason in the human mind, an assumption that is held as a cardinal principle of faith. Yet this faith is so automatically and generally accepted that we hardly recognize it as an essential basis for science.

*Revelatory Experiences*

One might think that religion and its theology have a patent on revelatory experiences. One might also think that scientific discovery consists merely in reasoning based upon existing knowledge. But revelations of new knowledge can also happen in the process of scientific discovery.

One famous case of revelation was the discovery of the benzene ring structure. The German chemist Kékulé had puzzled for some time over how carbon could form benzene and similar molecules. The story is that one evening, partly dozing in front of his fireplace, he dreamt of a snake

which curled around and took its tail in its mouth. He woke up. That's it – carbon atoms form a ring!

I have had such a revelatory experience. At the time I was working on what would become the maser and the laser, I had been researching ways of producing short waves for four or five years, but nothing I tried was producing the results I was looking for. And I was chairperson of a committee organized to consider what research was needed to produce short waves. Early in the morning just before a meeting of this committee in Washington, I walked out to a park to enjoy the fresh air. I sat on a bench looking at the azaleas freshly opened. And I asked myself: "Why can't we do this?" I went through the reasoning one more time, but this would not yield an answer. We ought to be able to use atoms or molecules, I thought. They are built in a way which produces short waves. But no, I'd been through that before. The problem was limits. posed by the second law of thermodynamics: you can't get more than a certain amount of power...Wait a minute! Wait a minute! The second law of thermodynamics doesn't have to apply if there is no definable temperature. I sat there for a few minutes. A revelation of sorts had occurred. I could see it in my mind. I took out a piece of paper and pencil and wrote down the numbers. Sure enough, the numbers made sense. One could build a practical short wave oscillator using molecules mostly in excited energy states and hence not describable by an ordinary temperature.

If we emphasize its setting, this story can even be endowed with a certain mystique. I had stayed overnight in a hotel with A. L. Schawlow. When I had awakened, he was still asleep. To avoid waking him I had slipped out. He was to become coinventor of the laser with me. The building looking out over the park was where Alexander Graham Bell had worked intensively but unsuccessfully on using light for communications, for which the laser has played one of its major roles. At the time, I did not even know about the closeness of Bell's former laboratory, but that was in fact the setting for this revelation.

Theologians might say that revelation both prompts faith and reflects on faith. As a research scientist, my faith came first and kept me inspired to work until a revelation occurred, one which confirmed my faith in the scientific endeavor.

### *Quantum Mechanics and Uncertainty*

Despite our faith in the logic and reliability of nature, at the subatomic level we find counter-intuitive phenomena, generally understood by the dis-

covery of quantum mechanics. Some of these phenomena must be thought of in terms of uncertainty, or to put it more strongly, of indeterminism.

Let us start with a question which has arisen frequently: Does light consist of particles or waves? Newton thought light was made of particles, but in the early part of the 19th century Thomas Young did interferometric experiments which convinced scientists that light is really made of waves. With the birth of quantum mechanics in the early part of this century, light took on aspects of both particles and waves. This duality is contrary to normal human intuition, and continues to be challenging. When we shine light on a glass window, some of it is reflected back while the rest passes through. Yet we should. and can ask: How does an individual particle of light, a photon, decide whether to bounce back or to pass through? At tempting to answer such a question leads to the Heisenberg uncertainty principle. According to this, we can never know for certain which particular photon will pass through the glass or be reflected. A fundamental uncertainty pervades the full extent of our knowledge of the physical world. The best we can do is predict the odds -the probability- that a given thing will happen, or that a given photon pass through or be reflected.

Causal determinism no longer applies. This is the conclusion derived from quantum mechanics, or from Heisenberg's uncertainty principle. Causal determinism seems to make sense at the level of day to day observation of any thing much larger than the atomic scale; but at the atomic level our science implies a heavy dose of chance operative in nature. Some scientists – for example Einstein – still convinced by their faith in the rationality of nature understood in terms of causal determinism, persisted in seeking to overcome uncertainty by positing the concept of hidden variables. This approach postulated hidden variables to represent as yet undiscovered forces which produce the quantum phenomena we observe. To these scientists the world of nature simply had to be deterministic, so such a force was assumed.

Bell's Theorem in the 1960s suggested a way in which the postulated existence of hidden variables could be tested. John Clauser at the University of California, Berkeley, first put the theory to experimental test, and revealed that no such hidden variables could be present. This has since been confirmed by many experiments. To his credit Clauser acknowledged that, even contrary to his own firm expectation, nature had spoken through an experiment announcing that no hidden variables exist.

With the advent of quantum mechanics, some religiously-oriented scientists such as Arthur Compton immediately claimed that God acts at the

quantum level, and, together with nature, can make quantum events occur the way they do. But there is a basic problem with this approach. Granting Heisenberg's uncertainty principle, along with the rejection of hidden variables, science leaves no room for God to interfere. To insert God as a determining cause makes little sense when what is observed scientifically is that no causal determinant can be at work here.

*Can we do Experiments in Religion?*

Is it possible to perform experiments about religious questions? The key to success in scientific research is that an experiment performed by one scientist is in principle repeatable by another scientist and, if valid, will produce a confirming result. Experiments can be repeated. Is such a thing possible with religious subject matter? My answer is a mixed one.

On the one hand, experiments and experience go together. Experiments are organized experience, so to speak. We have to recognize, of course, that certain areas of human experience are not repeatable and therefore not subject to what is ordinarily called experimentation. Each day we see things and do things that affect the actions of other people; we read history and learn about the sequence of events that brought us to where we are today. Daily activities and historical understanding represent experience which is in many ways very much like experimental observations, but it is normally experience of unique and unrepeatable events. Religious experience typically belongs in this category, as does some of social science. Theology, which among other things reflects on human experience, relies heavily on the history of unrepeatable events. But we evaluate these, applying whatever logic we can muster, perhaps subconsciously, along with intuition, to form our religious views.

Some dimensions of religious life may well be confirmable. Doubting Thomas for example, following the Easter resurrection of the crucified Jesus, wanted proof. He wanted to touch the wounds of the corpse now living in order to overcome his doubt regarding the truth of the resurrection claim (John 20:26-29). It is not unusual for a person of faith to want the same confirmation of belief that a scientist wants to find in the results of an experiment. We might think of Thomas as the first empirical Christian.

Prayer may provide us with another example of religious experience subject to experimental investigation. A recent study by Dr. Herbert Benson at Harvard undertook experiments to determine if prayer for the sick or injured has any influence on their recovery. The

results of this statistical study confirmed that, yes, prayer does in fact have a positive effect on the health of patients. The experiment was done with patients who knew they were being prayed for; an experiment without the patients knowing this still needs to be done.

Now, how should we think about such an experiment? Suppose we were to draw a strict line of separation between science and religion, what would we conclude? Prior to the experiment, prayer would have been considered strictly a religious phenomenon. Now that a successful experiment has been performed, it might then enter the domain of science. Yet prayer is prayer, regardless of the experiment. This is another reason why I do not agree with those who maintain a high wall of separation between science and religion. Instead, I would rather admit that science and religion are not discretely separated domains. Rather, they constitute two complementary modes of human understanding; and at least in some areas they share a common domain of knowing. In fact, I hesitate to put boundaries on either one, and expect that as we understand each more fully, they will more fully overlap.

*Creation and the Anthropic Principle*

One of the most significant points of shared interest between science and theological reflection is concern for the origin of the universe. What do we now know from science about the origin and history of the universe that may touch on what theologians believe about God's creating us and our world with a purpose? First, we now know that there was a unique time in the history of the universe. About 15 billion years ago it exploded with the "Big Bang" from a minuscular size to its present enormous extent. Afterwards, the sun and the earth came together, and life began. This is contrary to the intuitive beliefs of many scientists of the past that the universe has always been more or less the same; that there can be nothing unique about us nor in the history of our universe. What lies behind this beginning is the source of much scientific thought and speculation. The theologian can say that it was God's creation, and avoid the question of what then was God's origin. Scientists try to probe beyond this beginning, but we cannot avoid confronting the concept of a "beginning."

We have also learned from science that very special circumstances were necessary for us to be here. The early kinetic energy of the Big Bang explosion had to match the mass of material more closely than one part in a million million in order for the universe to both be long-lived as it is and also

to develop galaxies and stars. The nuclear and electronic forces in atoms had to have just the right ratio for this universe to have the rich variety of chemicals needed for our life. The gravitational force and nuclear reaction properties had to be very well matched to allow formation of long-lived stars. Two energy levels characteristic of oxygen and carbon nuclei had to be remarkably well matched for both carbon and oxygen to be abundant, as we need them to be. These and other remarkable "coincidences" have led to articulations of the "anthropic principle " – that the natural laws must conform to what is needed for human life. But this is only a tautology since of course we are here. What is interesting is the apparently very special conditions required by human life.

Also of particular interest is the close tie between life and the nature of our planet earth. Many planets are likely circling other stars; and so life may not be rare. In principle we must suppose that life may have developed in many locations. Yet, when we took at all the planets within our solar system, our Earth looks unique. Jupiter, Saturn, and the other large planets are too cold, too gassy, and inhospitable for anything like our kind of life. Mercury is too close to the sun and hot. Mars and Venus seem at first glance to be similar to Earth. Although life may have existed in the past on Mars, today it is cold and without an appropriate atmosphere.

Earth's sister planet Venus, earlier thought to be a promising planet for life, we now know is covered with a heavy atmosphere of carbon dioxide and the surface is hot enough to melt lead. Actually, the atmospheres of both Venus and Earth are thought to have begun similarly, with carbon dioxide being emitted from their inner material and accumulating in the atmospheres of each. Yet, life started at just the right point in Earth's history, just before the greenhouse effect became overwhelming and the planet became too hot. Life on Earth started about a billion years after planet formation, at just the right point where it could change carbon dioxide into free oxygen. It continued to keep the carbon dioxide under control, preventing Earth from becoming overheated like Venus. Now how does one evaluate this? I hesitate to draw hard and fast conclusions. Yet these observations are impressive. Freeman Dyson faces the situation with the following statement:

> I conclude from the existence of these accidents of physics and astronomy that the universe is an unexpectedly hospitable place for our living creatures to make their home in. Being a scientist, trained in the habits of thought and language of the twentieth century rather than the eighteenth, I do not claim that the architec-

> ture of the universe proves the existence of God. I claim only that the architecture of the universe is consistent with the hypothesis that mind plays an essential role in its functioning.[6]

Regardless of what one may think this can say about God, what is striking here is that scientific evidence leads to a feeling and hypothesis that the course of natural history is guided at least in part by an intelligence and a purpose.[7]

Physicists have been brought much closer to questions of interest to theologians as they succeed in delving more fundamentally into the origins of our universe and the nature of physical laws. Relativity and quantum mechanics have also changed our basic concepts since the last century. Strict causal determinism, for example, has gone. And while as a result of developments such as relativity and quantum mechanics we now understand much more than we did in the nineteenth century, I believe physical scientists have become more modest about how completely we really understand our universe.

It is particularly striking that as our experiments and thoughts have penetrated new realms – high velocities and high gravitational fields in the case of relativity, tiny particles of atomic size in the case of quantum mechanics – our basic concepts have been altered, but without changing the validity of most of our previous physical laws under the circumstances where they were previously tested. For macroscopic objects we still teach, use, and intuitively think in terms of Newtonian mechanics, even though our views of its meaning have radically changed. For ordinary velocities and ordinary gravitational fields, we still use and think intuitively in terms of a simple three dimensional space and an independent time, even though general relativity provides a rather different basic view. This may lead to the conclusion that time-tested ideas, either in science or in religion, are likely to continue to have some kind of validity even if in the distant future we understand enough to revolutionize our thinking in either area.

[6] Freeman Dyson, *Disturbing the Universe* (New York: Harper and Row, 1979), p. 251.

[7] Elsewhere Freeman Dyson writes: "The universe as a whole is hospitable to the growth of mind. The argument here is merely an extension of the Anthropic principle up to a universal scale...the argument from design still has some merit as a philosophical principle. I propose that we allow the argument from design the same status as the Anthropic Principle, expelled from science but tolerated in metascience. The argument from design is a theological and not a scientific argument." *lnfinite in All Directions* (New York: Harper, 1988), p. 297.

*Chance in Biology*

The biologists may at first seem fortunate because they have not run into brick walls such as physicists hit in finding quantum or relativistic phenomena that are so strange and different. But this may be because biologists have not yet penetrated far enough towards the really difficult problems where radical changes of viewpoints may be essential. In any case, biology is now in a stage where no basically new phenomena are obviously needed for its progress, and current work can be interpreted in terms of known laws of chemistry and statistics. We do not really know just how the first forms of organized life started nor whether initiation of life was very likely, even given favorable circumstances on Earth. We do not even know the details of under just what circumstances on Earth it began. Yet to many scientists, life seems a natural and almost automatic event given that the physical laws and nature of our planet turned out the way they did. Jacques Monod puts it strongly: "Chance alone is at the source of every innovation, of all creations in the biosphere."[8] Stephen Jay Gould says, "We are the accidental results of an unplanned process."[9] But some, like the evolutionist Ernest Mayer, are nevertheless impressed. He writes: "Virtually all biologists are religious in the deepest sense of this word...The unknown, and maybe the unknowable, instills in us a sense of humility and awe."[10]

I believe biology may yet encounter problems which may fundamentally change our views, and wish I could watch its development over the next century to learn whether this becomes true. For example, really understanding the human brain seems an awesome task. Clearly we can understand much more than we do at present. We can, for example, imagine "intelligent" computers designed to do many of the things our brains do. But can they have anything like the sense of consciousness or the sense of free will that humans possess? The brain is immensely complex. It contains ten billion neurons, each of which has about ten thousand synapses. This represents about a million gigabits of information, interacting in complex modes. The human brain can understand many complex devices. But we

[8] Jacques Monod, *Chance and Necessity* (New York: Random House, 1972), p. 112.

[9] Stephen Jay Gould, "Extemporaneous Comments on Evolutionary Hope and Realities," in *Darwin's Legacy,* Charles L. Hamrum, ed., Nobel Conference XVIII (San Francisco: Harper and Row, 1983), p. 102.

[10] Ernest Mayer, *The Growth of Biological Thought* (Cambridge: Harvard University Press, 1982), p. 81.

can wonder whether any device can ever really understand itself, or only other devices which are somewhat simpler than that which understands them. Can the brain really understand itself?

*Free Will*

What do we really know about free will? I suspect that every scientist, like most humans, assumes that free will exists. It is part of our everyday reality as human beings. With quantum mechanics the world is no longer deterministic. But present science says that the chance directions in which quantum mechanics allows it to develop cannot be influenced either by a divine force or by anything like the usual concept of free will. Yet although the usual concept of free will is not consistent. with our present understanding of science, we almost all assume we have some free will and live accordingly.

How can we understand our sense of free will as consistent with today's science? It is possible that free will as we experience it is a delusion. Perhaps it does not actually exist. Perhaps it can be explained simply as a delusion that has proven to have great survival value in the process of evolution. Religion, like free will, might also be explained as a delusion contributing to our evolutionary advantage, increasing the survival potential of human society. So perhaps we are just kidding ourselves when we think we observe ourselves making free choices or responding to God's will.

In spite of uncertainties, like so many others I have a fundamental sense that free will is there. It exists. I feel that I have free will and act according to it. I look around and make judgments about things. I make decisions. I take actions. I also have a sense of divine presence in the universe and in my own life and try to act out of the sense of freedom concomitant with this presence. Our sense of free will needs to be explained, or perhaps accepted rather than explained away. The same is true, I believe, of our sense of the divine. As we pursue scientific and religious understanding, how will our views of such matters develop?

*Conclusion*

Once the necessities of life are available, questions about its orientation, value, and meaning, which are the emphasis of religion, are more pressing and critical than those about the structure of our universe, the emphasis of science. This may be why human societies have developed and codified religious ideas much sooner than scientific ones. But in the last few centuries

science has, by contrast with religion, made remarkable progress, and this has put emphasis on its methods and validity. Yet our understanding of both science and religion are dependent on human reasoning, on evidence, and on faith. And both involve profound uncertainties.

As humans, we face life. Decisions cannot be avoided; we need to choose our orientation, actions, and directions even if we understand imperfectly. Each of us decides in our own way. Yet we all make these decisions based on our experience, what our parents have told us, observations of the people and society around us, our understanding of human history, the evidence we have, and whatever logic and intuition we can muster. While assumptions and decision about our lives cannot be avoided, we also need to be open to change, listening for revelations and looking for new understandings of reality. Relativity and quantum mechanics have revolutionized science. We must be prepared for revolutions in our thinking, both in science and religion. But we can at the same time expect that our past reasoning and beliefs have important, even if imperfect, validity.