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Science-Fostering Belief— Then and Now

Christopher B. Kaiser

Some nineteenth-century historians and philosophers portrayed the relationship between science and religion as one of open warfare. By the end of the twentieth century, this warfare model was largely abandoned by historians of science. It is now generally recognized that early modern scientists were motivated by various religious beliefs. However, historians and philosophers still often assume that the beliefs of early scientists either were abandoned by later scientists or became peripheral to scientific work. Any beliefs that scientists rely on today are thought to be merely common-sensical and secular in spirit.

What seems to have escaped the notice of historians and philosophers alike is the fact that some of the beliefs of early modern scientists have persisted in surprisingly consistent forms. These beliefs are so basic to scientific endeavor that they it could not be sustained without them. Modern science actually turns out to be a faith-based enterprise.

In support of this revisionist position, I shall identify two distinct beliefs having to do with the comprehensibility of the natural world that occur in the writings of early modern scientists like Johannes Kepler. I shall discuss some of the forms those beliefs took in medieval Christianity and in Reformers like Philip Melanchthon in order to show their specifically theological character. Finally I shall illustrate the survival and vitality of these beliefs in modern scientists like like Albert Einstein and Paul Davies.¹

atural science can be defined as the human endeavor to explore and understand all accessible features of the space-time world, even (and especially) those that are only accessible through the use of sophisticated technologies that probe the heights and depths of the universe. But this simple definition implies that some people have the audacity to believe they can discern anything beyond what is required for daily life. Such Science-Fostering Belief, as I shall call it, constitutes part of the software that motivates scientists and sustains them in their endeavors.²

But why? Why should anybody believe that they could use their brain to go beyond what is already known about the universe? Undoubtedly most modern scientists do not consciously articulate this belief as the starting point of their daily work. Science-Fostering Belief has become a fixture of the culture in which young scientists develop (as in my own experience) and in which their work is sustained. It may only be tacit for the majority of trained scientists on a daily basis which is true of believers of all sorts.³ The question is still why any culture or subculture that ever existed should have cultivated and sustained such an audacious belief.⁴

Exploring the cultural roots of Science-Fostering Belief will lead us to an examination of the historic "creationist tradition" and to rethink the relationship between scientific and theological endeavor. In spite of the fact that the interests of science and theology have at times conflicted, the two are much more closely related than we often assume, particularly when you probe the foundations on which the training and work of scientists rests. The tendency to treat them as two



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[The belief that some people] can discern anything beyond what is required for daily life [is what I call] Science-Fostering Belief ...

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In spite of the fact that the interests of science and theology have at times conflicted, the two are much more closely related than we often assume, particularly when you probe the foundations on which the training and work of scientists rests. The tendency to treat them as two separate phenomena ... is a peculiar result of modern secularization.

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separate phenomena – associated with irreconcilable opposites like skepticism and faith, respectively – is a peculiar result of modern secularization. Here I take issue with Chet Raymo's characterization of good scientists as natural skeptics in contrast to "true believers."⁵

The Contingency of Belief: Four Clarifications

First we have to reckon with the fact that the founders of modern science were Europeans who were raised as Christians and who approached their work within an intellectual framework strongly influenced by biblical beliefs. The result is that one particular religious tradition is singled out for examination in this study. It is not exclusively a Christian tradition, because its roots go back to the cultures of the ancient Near East, Israel, and Greece. The "creationist tradition" that Christianity inherited was in the process of formation centuries before Christianity became a distinct religion.⁶

It may well be the case that, of all the historic cultures of the world, the vast majority would not have had the inclinations or beliefs needed to develop modern science on their own. It does not follow, however, that no other cultures have the belief structure needed to support scientific endeavor or even that progressive science might not have originated outside of Western Europe.

This is an immense area for investigation. In order to make the point, we need only cite a few examples. Ancient Chinese texts like Master Lü's Springs and Autumns (c. 240 BCE) clearly affirm the lawfulness of the complementary forces that emerge from the Supreme Oneness.7 Such beliefs are very similar to those we shall discover at the foundation of modern Western science. The Holy Qur'an portrayed the sun, moon, and the heavens as subject to the legal ordinances of Allah.8 In the Middle Ages, Islamic science developed mathematical and experimental techniques that did not appear until centuries later among early Western scientists.9 So there are certainly other theological traditions to explore besides Christianity. But we are focusing on the cultural frame at the foundation of Western science, so we must concentrate on the Judeo-Christian background of modern science as a matter of historical contingency.

On the other hand, there are definite constraints on science-fostering cultures. While the kind of beliefs needed to foster scientific endeavor need not be uniquely Christian, they are neither universal nor arbitrary. A culture that can promote scientific research must inculcate the belief that the universe is intelligible in principle, and that humans are special in their ability gradually to learn all about it. Humans also need be made aware of their limitations, and most religious traditions do a good job at that. But forms of either skepticism or religion that undermine confidence in the lawfulness of the universe or the intelligence of humanity will not be able to sustain scientific endeavor over the long term.

The second preliminary point to be made is that no human culture was ever predetermined to cultivate the efforts of scientists.¹⁰ Today we often take such support for the sciences for granted. We know that a career in science is possible for anyone with the ability and the inclination to pursue the subject. Universities and research institutes provide the resources to make such careers a possibility. Without such a belief and the institutions that sustain it, scientific endeavor as we know it would not be possible.

Cross-cultural travel (or reading) reveals that such institutions are not universal. They are becoming more prevalent as industrial society globalizes, but there are still many areas of the world where people have more pressing things to attend to. Sustainable research institutes have only originated within the last few hundred years in one small corner of the world.11 Prior to that time, civic leaders were more likely to support the building of churches or the quest for the philosopher's stone than they were to support scientific endeavor as we know it. Historically speaking, therefore, the emergence of modern science was far from inevitable in Western Europe to say nothing of other parts of the world.

Third, there is no need to suppose that every individual will value or support the work of scientists even in a culture that takes the possibility of scientific endeavor for granted. Western Europe and America are highly scientific cultures, yet there has been and continues to be skepticism, if not downright opposition, with regard to the pursuit and support of scientific research. Cultures of belief establish certain propensities, but they are far too conflicted to have exactly the same effect on all of their members.¹²

Cultures differ enormously in the kind of occupations they make possible. The culture of India has traditionally provided a way for many (if not most) individuals to break free from their inherited social ties and seek individual enlightenment once they have fulfilled their obligations to family and society. That life-trajectory is a distinct possibility in Indian life even though only a minority of people is inclined to pursue it, and modernist critics may even oppose it. The same is true of Western Europe in regard to the development of careers in science. So a sciencesustaining culture need not be ideally suited for scientific endeavor any more than the cosmos in which we live is readily intelligible or the human brain is ideally suited for scientific research.

The fourth point is that I aim to reverse the common perception of the science-theology relationship as one of necessary conflict. There certainly have been instances in which religiously motivated authorities have opposed particular scientific ideas. The Congregation of the Holy Office's pressuring Galileo to renounce his Copernican convictions and the prosecution of John Thomas Scopes for teaching the evolution of humanity in an American public school are two of the best known examples.¹³ The publicity that has grown up around isolated instances like these has sometimes been generalized into the dogma that religious faith is inherently opposed to scientific endeavor.

In order to counteract this impression, I shall give an example of a scientist who was sustained by the creational teachings of the Church-scientists as believers, then. I shall also give some examples of scientists who were not committed to a particular creed, but who recognized the importance of biblical teachings for their profession-scientists as believers, now.

Most historians of science have already corrected the record on this matter—they are not my concern.¹⁴ But Church historians and historians of theology tend to ignore the role of religious beliefs in the history of science. I shall make a case for broadening and thickening our view of historical theology in order to trace its implications for secular disciplines like the natural sciences.

The Origin of Science-Fostering Belief

With these preliminary points in mind, we can now focus on the main question of this article: what was the cultural source of the conviction of early modern scientists that they could probe beneath the surface phenomena and discover the underlying laws of nature? What made them think that the enormous amount of time they spent investigating seemingly intractable problems would lead to improved understanding? Why did anyone ever dream that questions as abstruse as the balance of matter and anti-matter or the circulation of the mantle in the Earth's interior could actually be answered?

There are two topics that we need to address: the historical origin of Science-Fostering Belief, and what that belief looks like in the work of recent scientists—beliefs in science—then and now.

Early Modern Astronomy: The Case of Johannes Kepler

In the late sixteenth century, Johannes Kepler (1571–1630) studied theology and astronomy at the University of Tübingen. He became convinced that Copernicus was



right—the ancient idea that the earth was the center of the universe was wrong; instead, the earth moved through space, revolving around a point very near the center of the sun. As Kepler's personal correspondence indicates, questioning the received wisdom of the ages took considerable intellectual courage.¹⁵ This courage was based on his dissatisfaction with tra-

Johannes Kepler¹⁶

ditional (Ptolemaic) astronomy and his belief that a better understanding of things was possible.

Kepler was fascinated with the arrangement of the orbits of the six known planets (visible to the naked-eye). As stated in the "Greeting to the Reader," at the outset of Kepler's very first publication, *The Secret of the Cosmos* (1596), there had to be a good reason for this arrangement, but neither the treatises of ancient writers like Ptolemy nor Copernicus's own work gave an adequate answer.¹⁷

Kepler originally thought he could solve the problem in terms of solid geometry.¹⁸ It so happens that there are just five regular polyhedrons—solids with faces that all have the same shape and size (tetrahedron, cube, etc.). That is exactly the same as the number of intervals between the orbits of the six known planets (Mercury, Venus, Earth, Mars, Jupiter, and Saturn). Could that be a mere coincidence? If not, it should be possible to construct a model for the orbits of all six planets by imagining them as circles on a set of giant spheres with the five regular solids nested between them (see figure 1).

The cognitive basis for this imaginative construction was Kepler's belief that there was a rational solution to the problem. An astronomer should be able to construct a mathematical model that would demonstrate the basic



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laws involved. Kepler expressed that belief at the outset of his 1596 treatise:

It is my intention, reader, to show in this little book that the most great and good Creator, in the creation of this moving universe and the arrangement of the heavens, looked to those five regular bodies ... and that God fitted to the nature of those solids the number of the heavens, their proportions, and the law of their motions.¹⁹

In the beginning, God had constructed the planetary system according to the laws of solid geometry. Since the basics of solid geometry were known, a miniature model of the planetary system could be constructed. The idea of building a mathematical model for a natural system is standard procedure today. For Kepler the idea was based on belief in divine creation, which he inherited from a longstanding creationist tradition.²⁰

We know today that Kepler's geometrical model does not work. It was based on incomplete data: there were at least two more planets to account for that could not be seen prior to the invention of the telescope. So there are aspects of Kepler's thinking that would be bypassed in the subsequent development of astronomical science. What was enduring was his belief. Kepler was convinced that there must be a discernible reason for the arrangement and motions of the planets. That conviction motivated his research throughout his career even though he never completely solved the problem that he started with.

I must emphasize the fact that Kepler's belief was not based on his (limited) success. Rather it preceded his work and motivated it. Being a pious Lutheran who immersed his life and work in theological study and prayer, he started with his inherited belief in God as a wise Creator and inferred that the planets God created must follow simple laws.²¹ Creational belief was the foundation of Kepler's endeavor as a scientist.

The rest of the story is well known. Kepler eventually gained access to the latest, most detailed observations — those made by Tycho Brahe and his associates at his observatory in Denmark — for the changing position of Mars in the night sky. It was known that the orbit of Mars was not exactly circular. Kepler believed it possible to explain the data in terms of a simple pattern that could be expressed mathematically. But proving it was a long, laborious process. Today the entire problem could be easily solved using a simple computer algorithm. But Kepler relied on his creational beliefs to sustain his work for years using the rudimentary mathematical methods of his time.²² His work is a good example of the Science-Fostering Belief that we are seeking to describe.

By the year 1605, Kepler finally demonstrated a solution to the data for Mars. The changing position of Mars could be explained by assuming that its orbit was an ellipse rather than a circle.²³ With the advantage of later scientific knowledge this may seem like a trivial step. However, the shift from circles to ellipses was more radical than just trying a new formula – Kepler was assigning a fundamental role in nature to a shape that had previously played no practical role in everyday life.²⁴ In fact, most astronomers stayed with the simpler idea of circular orbits until Isaac Newton published his demonstration of elliptical orbits from the inverse square law of gravitation in 1687.25

Kepler also discovered the principle that governed the motion of each planet along its elliptical orbit (later known as the law of "equal areas in equal times") and ten years later he devised a formula that related the period of revolution to the size of the orbit for each of the planets.²⁶

Kepler synthesized his hard-earned results in a treatise entitled, *Harmonics of the*



Fig. 1. Kepler's Early Model for the Planetary Orbits²⁸

Universe,²⁷ published twenty-three years after his first publication. As always, he was forthright about the basic convictions that had sustained him in his efforts:

Geometry, which before the origin of things was coeternal with the divine mind ... supplied God with patterns for the creation of the world and passed over to human nature along with the image of God ...²⁹

Kepler's Science-Fostering Belief had at least two distinct components. The belief that the universe is ordered by mathematical laws [and] the belief that mortal beings like humans have the intelligence needed to discover these cosmological laws ...

Here Kepler restated his long-standing conviction that God had created the heavens according to the principles of basic geometry. But the quotation adds a second beliefthe biblical idea that God had created humanity in the divine image (based on Gen. 1:26-27). Kepler also cited Plato and Proclus to show that geometry was not derived from human experience. It was present in the mind of each human from birth and only needed to be elicited by a good teacher.30 Since geometry was an innate form of knowledge of the patterns that God used in creation, Kepler reasoned that it must have been part of the divine image in humanity. In fact, he described the human capacity for geometry as a ray of that divine image that was infused into the human soul at birth.³¹ In this way, Kepler sustained his own belief not only that there was an answer to the puzzle of the planetary orbits, but that human beings had the ability (and the obligation) to discover it.

From this passage in *Harmonics of the Universe*, it appears that Kepler's Science-Fostering Belief had at least two distinct components. The belief that the universe is ordered by mathematical laws is one of them—Kepler thought of it largely in terms of geometry as the pattern of creation. The second component is the belief that mortal beings like humans have the intelligence needed to discover these cosmological laws—again Kepler thought in terms of geometry implanted in the human mind. In other words, there is a striking correspondence between the depths of the human psyche and the deep structures of the universe, between mind and matter—not a perfect correspondence, perhaps, but more than one might expect from a pragmatic assessment of human nature. Kepler frequently noted the importance of this subjectobject correspondence for scientific endeavor. This conviction was what one recent historian has called the "mainspring of his life's work."³² It was clearly stated, for example, in his correspondence of the late 1590s, years before his major breakthrough. In a letter addressed to his astronomy teacher, Michael Mästlin, Kepler (1597) explained that

... God, who founded everything in the world according to the norm of quantity, also has endowed humanity with a mind which can comprehend these norms. For, as the eye for color, the ear for musical sounds, so is the human mind created for the perception not of any arbitrary entities, but rather of quantities ...³³

Kepler's letter portrays the human mind as being adapted to discern the mathematical structures of creation in the same way that the eye is adapted to perceive color.³⁴ Although Kepler does not refer in this passage to the idea of the divine image in humanity, he does base his belief on the idea that humans are God's special creatures. God ensured that humans would have the innate ability to discover the norms according to which the world and everything in it were created.³⁵

The role of the divine image in humanity is more clearly stated in another of Kepler's letters, written just two years later (1599):

Those [laws which govern the material world] are within the grasp of the human mind. God wanted us to recognize them by creating us after his own image so that we could share in his own thoughts ... and, if piety allows us to say so, our understanding is in this respect of the same kind as the divine, at least as far as we are able to grasp something of it in our mortal life.³⁶

As the context of the passage indicates, Kepler felt himself compelled to justify his efforts to improve on the science of the ancients. Some of Kepler's critics apparently thought that enhanced knowledge of such recondite subjects was forever beyond the understanding of beings like humans who were confined to live on earth. So Kepler's reference to a well-known biblical idea (Gen. 1:26-27) provided needed theological support. But it also came from the heart of his own conviction formed through his theological training at the University of Tübingen. The willingness to question received knowledge and to strive for deeper understanding was generated by religiously founded beliefs. For some of Kepler's contemporaries, scientific understanding and religious belief apparently seemed contradictory, but for Kepler himself they were not only consistent, but mutually affirming. The theological background for his conviction is to be found in the writings of Martin Luther and Philip Melanchthon.

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For Davies, the doublefoundation of rational order and human understanding is a "tantalizing mystery," really a double-mystery. But there is a third mystery implied in Davies' statement about the "miracle" of science ... the mystery of why scientists believe the universe to be intelligible.

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Kepler's Background in Lutheran Creational Theology

The example of Kepler shows that we are dealing with a culture of belief that was deeply informed by biblical teachings. It is worthwhile citing the founders of Kepler's immediate theological tradition, Luther and Melanchthon.³⁷ Two of the most widely available treatises on the creation of humanity were Luther's "Lectures on Genesis" (published in 1544) and Melanchthon's treatise "On Christian Doctrine" (*Loci communes*, 1555). The two treatises may be treated together because they were written and revised over the same period of time and because Luther's lectures were strongly influenced (if not partly written) by Melanchthon.

Luther's Lectures on Genesis make it clear that the creation of the first humans in the divine image entailed "the most dependable knowledge of the stars and of the whole of astronomy."38 This original knowledge was largely lost due to human rebellion against God, but a spark of that original life is still evidenced in human efforts to "understand the motion of the heaven or measure the heavenly bodies."39 Melanchthon's Loci communes was more specific and listed "understanding about number and order" among the gifts of God that may still be observed in humans.⁴⁰ So Kepler's beliefs were not at all idiosyncratic or arbitrary. They were rooted in the teachings of his church, particularly as they were mediated by the writings of Luther and Melanchthon and the teachings of mentors like Michael Mästlin and Jakob Heerbrand.41

Kepler's beliefs about creation were not unique to Lutheran circles. They were quite typical of Western European culture in the sixteenth and seventeenth centuries. Other figures could be examined with basically the same result. Some prominent examples of natural philosophers expressing the identical beliefs to Kepler's are Lefèvre d'Étaples, Paracelsus, Giordano Bruno, Francis Bacon, Isaac Beeckman, René Descartes, and Walter Charleton.42 Our extended examination of Kepler suffices to establish the role of such beliefs in early modern science and to outline the nature of creational beliefs particularly as they were passed on to founders of modern physics.

Science-Fostering Belief in Modern Physics

What does Science-Fostering Belief actually look like in the work of representative modern scientists? As I stated earlier, the beliefs of most modern scientists are mostly tacit in everyday practice. The best examples for our purposes are scientists who reflect on the epistemology of their discipline. The ones we shall look at are Albert Einstein, Henry Margenau, and Paul Davies. Even though these writers differ in many ways, their beliefs are quite characteristic of their scientific culture and will give a good sense of the Science-Fostering Belief that they inherited from early figures like Kepler.

We shall review these three scientists in reverse chronological order, beginning with Davies in order to illustrate the role of belief in present-day physics. Then we shall turn to Margenau and Einstein in order to illustrate the role of belief at the foundations of modern physics (relativity and quantum theory). Einstein's historical insight about the cultural foundation of early modern science will point us back to Johannes Kepler and the historic creationist tradition.

A Present-Day Cosmologist: Paul Davies

My first example is the 1995 Templeton

laureate, Paul Davies.⁴³ In several important articles and most eloquently in his 1992 book, *The Mind of God: The Scientific Basis for a Rational World*,



Paul Davies

Davies drew attention to what he calls the "great miracle of science":

The success of the scientific method at unlocking the secrets of nature is so dazzling [that] it can blind us to the greatest scientific miracle of all: *science works*. Scientists themselves normally take it for granted that we live in a rational, ordered cosmos subject to precise laws that can be uncovered by human reasoning. Yet why this is so remains a tantalizing mystery.⁴⁴

Davies clearly articulates the basic point of this articlethat the pursuit of science is based on belief. In fact, he is quite specific in stating that there is a dual-belief at the foundation of scientific endeavor: First, scientists believe that the cosmos is rationally ordered – that it is governed by precise (mathematical) laws of some sort. This is an article of faith since science does not tell us where that rational order or those mathematical laws come from. Second, scientists believe that human minds are actually capable of understanding that rational order-they have the scientific intelligence needed to develop mathematical models and rational formalisms that will test positively against data gathered in the laboratory and even against data gathered from the farthest reaches of space-time. These two beliefs correspond to the dual-belief that Kepler inherited from his theological tradition.45

The burden of Davies' quotation is not just that this dual-belief—rational order and human understanding exists, but that modern scientists "normally take it for granted." It has become almost self-evident to working scientists today despite the fact that neither the existence of a rational order nor the possibility of human understanding is at all obvious in itself.

For Davies, the double-foundation of rational order and human understanding is a "tantalizing mystery," really a double-mystery. But there is a third mystery implied in Davies' statement about the "miracle" of science. In addition to the mysteries of rational order and human understanding, there is the mystery of why scientists believe the universe to be intelligible. This belief is the cultural foundation of scientific endeavor that we have found in the creationist tradition leading up to Kepler.

A Philosophical Physicist: Henry Margenau

The fact that scientific endeavor is motivated and sustained by faith was not realized for the first time by Paul Davies. Any number of writers could be cited on this topic. One of the clearest of the previous generation was Henry Margenau (1901–1997), a professor of physics and natural philosophy at Yale University (1950–1969). In a philosophical study, published in 1961, Margenau explored what he called "the new faith of science," by which he meant the set of beliefs to which all working scientists are personally committed even though they are "not subject to logical and empirical proof" and are often even contradicted by the difficulties encountered in scientific research.⁴⁶ As we have seen, this faith was not quite as new as Margenau believed: it is the same Science-Fostering Belief we have seen in the writings of Kepler and Melanchthon.

Margenau was haunted by the fact that scientists might well regard their efforts as futile. He described the difficulties that nuclear physicists were experiencing in constructing a field theory for nuclear forces. In the 1950s, new "elementary particles" were being discovered in highenergy experiments, and there were seemingly intractable mathematical problems in the theoretical calculations. Any scientist who had to work on such problems for years and who saw "little but chaos" might well become pessimistic about the long-term prospects of their discipline. What prevented scientists from giving up under such conditions, Margenau observed, was an "over-arching faith":

[The scientist] holds with the fervor of a religious conviction that his task is meaningful, that the history of science does converge in the limit upon a set of knowledge, laws and principles that are unique, categorical, and all inclusive.⁴⁷

Margenau's point here corresponds to the first article of faith we found in Davies' writings: "that we live in a rational, ordered cosmos subject to precise laws." But Margenau saw this belief as something more than what scientists take for granted. It was a personal commitment made with the "fervor of religious conviction."

Margenau's analysis of the "faith of science" focuses on the belief that the cosmos is rationally ordered. ...

According to [Margenau's] catechism, no one may ever completely understand the laws of the cosmos, yet those laws do exist and there is no insurmountable obstacle that can prevent scientists from getting successively closer approximations.

Margenau's analysis of the "faith of science" focuses on the belief that the cosmos is rationally ordered. Even though, he is not so specific about the complementary belief that humans are capable of discerning that order, this second belief is implied in his optimism about the prospects of eventually reaching a final theory. It is also implicit in the "catechism" Margenau developed to express the faith that sustained scientific research. This catechism had a total of six articles. If Margenau wrote today, he might call these, "Six Impossible Things Scien-



Like Davies and Margenau, Einstein clearly identified the twin beliefs that underlie scientific endeavor ... But Einstein was more explicit ... about the history of the beliefs he had inherited. Even though he was strongly critical of organized religions, Einstein traced his intellectual heritage back to the "sphere of religion."

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tists Believe before Breakfast."⁴⁸ Here I shall list just three of them, which read as follows:

- (1) I believe that the search for truth is a never-ending quest, yet I pledge myself to seek it.
- (3) I recognize no subjects and no facts which are alleged to be forever closed to inquiry or understanding; a mystery is but a challenge.
- (5) I believe in the convergence of the scientific laws upon principles that are all embracive, though they may never be completely within our reach.⁴⁹

According to this catechism, no one may ever completely understand the laws of the cosmos, yet those laws do exist and there is no insurmountable obstacle that can prevent scientists from getting successively closer approximations. Scientific endeavor is thus a process of "continual self-correction toward an ideal limit of understanding which is forever approached and yet never fully attained."⁵⁰ As Margenau stated, every mystery should be viewed as a new challenge.

Henry Margenau was a physicist and a philosopher. We might even call him a "theologian of scientific endeavor" in that he consciously articulated the beliefs that motivate scientists and showed the religious dimensions of science as a human endeavor.

At the Foundation of Modern Physics: Albert Einstein

Going back one hundred years, to the time when the foundations of relativity and quantum theory were being developed, Albert Einstein also recognized that faith lay at the foundation of his own work and that it had a religious character. The basic points we have seen in Davies and Margenau recur throughout Einstein's epistemological writings.⁵¹ For example, he stated the importance of assuming the rationality (or intelligibility) of nature itself:

Certain it is that a conviction, akin to religious feeling, of the rationality or intelligibility of the world lies behind all scientific work of a higher order.⁵²

The creative scientist must be entirely convinced of intelligibility in the depths of the natural world, the object of scientific work.⁵³ But the scientist must also assume some connection between subject and object in order for the natural world to be intelligible to humans. As Einstein reflected on his own scientific work, particularly in relativity theory, he observed that he had always approached his work assuming a primordial connection of some sort between the human scientist and nature. For Einstein there was no logical bridge between the phenomena and the principles that explain them that could ever take the place of disciplined human intuition. Therefore, the only way to explain how applicable concepts could arise in the scientist's mind was to assume a "pre-established harmony" between the two.54

Using this well-known phrase from Leibniz, Einstein argued for a "pre-established harmony" between the human mind and nature that could not be explained in terms of any mechanism, whether logical or natural.⁵⁵ He also borrowed a striking phrase from Kant to formulate one of his most cogent statements of the problem: "the eternal mystery of the world is its comprehensibility." As Einstein explained Kant's point in his own words: "... the world of our sense experiences is comprehensible. The fact that it is comprehensible is a miracle."⁵⁶

Einstein described this philosophical idea of "pre-established harmony" or "comprehensibility" in theological terms as a matter of "belief" or "faith."⁵⁷ He confessed his own firm belief in "a superior mind" that revealed itself in the laws of nature,⁵⁸ and he stated the importance of intellectual humility in the face of "reason incarnate" in the world—incarnate yet inaccessible to the human mind in its profoundest depths.⁵⁹

Like Davies and Margenau, Einstein clearly identified the twin beliefs that underlie scientific endeavor: (1) that the world is governed by mathematical laws; and (2) that human reason is capable of grasping those laws. But Einstein was more explicit than our previous two examples about the history of the beliefs he had inherited. Even though he was strongly critical of organized religions, Einstein traced his intellectual heritage back to the "sphere of religion." Here is the way he put it in a 1941 essay entitled, "Science and Religion":

Science can only be created by those who are thoroughly imbued with the

aspiration toward truth and understanding. This source of feeling, however, springs from the sphere of religion. To this [sphere of religion] there also belongs the faith in the possibility that the regulations valid for the world of existence are rational, that is, comprehensible to [human] reason.⁶⁰

Einstein repeatedly pointed to this larger "sphere of religion" in order to explain the scientist's belief in the comprehensibility of the natural world. In the context of the quote just above, he referred back to the ideas of Christian natural philosophers like James Clerk Maxwell (1831–1879), who had an immense influence on Einstein's own teachers.⁶¹

Einstein also pointed out that founders of modern science were people of profound religious faith.

What a deep conviction of the rationality of the universe and what a yearning to understand, were it but a feeble reflection of the Mind revealed in this world, Kepler and Newton must have had to enable them to spend years of solitary labor in disentangling the principles of celestial mechanics! ... Only one who has devoted his life to similar ends can have a vivid realization of what has inspired these men and given them the strength to remain true to their purpose in spite of countless failures.⁶²

Belief in the intelligibility of the cosmos made the solution of scientific problems seem possible to natural philosophers like Kepler and Newton long before it was an everyday occurrence as it is commonly thought to be today. Even though Einstein rejected any notion of a personal God who answers individual prayers and who judges people according to their individual choices,⁶³ he recognized deeper roots for this faith in the Psalms and the Prophets that had inspired early European scientists.⁶⁴

If Einstein, Margenau and Davies are correct in their observations, scientific endeavor still depends on the twin beliefs in universal laws of nature and in human intelligence to match those laws. And if Einstein was correct in his understanding of history, the emergence of modern science itself was dependent on a religious heritage that engendered those very beliefs.

Scientists are believers. This simple idea has implications for our views of both science and theology. A suitably thick description of scientific endeavor must therefore include a theological dimension.⁶⁵ It must portray the embedding of modern science in the cultural history that has provided the necessary motivation (Kepler), conviction (Einstein), and persistence (Margenau) needed for sustained endeavor.

Conversely, a suitably thick description of historical theology must include a scientific dimension. It must include the thinking of scientists like Kepler, Einstein, Margenau, and Davies who articulate beliefs that ultimately derive from the biblical tradition. It should also make room for the hundreds of scientists (and other lay professionals) who live out those beliefs even if they do not consciously articulate them.

Notes

- ¹This paper was presented at the 61st Annual Meeting of the ASA, at Calvin College, 31 July 2006. It is based on the third chapter of Kaiser, *Foundations of Science in Theological Perspective: Toward a Theology of Scientific Endeavor* (London: Ashgate), scheduled for publication in 2007.
- ²I use the terms "belief" and "human psyche" in order not to limit our investigation by the strictly cognitive associations of the comparable terms "ideas," "mind" and "intellect." Belief in the possibility of science is only part of the software needed. It must be supplemented and reinforced by years of training in mathematics and other disciplines. Here we are concerned with the beliefs that motivate some people to undergo such training and devote their lives to the practice and propagation of what they have learned. Science-Fostering Beliefs is the cultural foundation of scientific endeavor viewed upward and forward in history. The cultural foundation of scientific endeavor is Science-Fostering Beliefs viewed looking downward and backward in history.
- ³Tacit knowledge (or awareness) is knowledge upon which people rely without necessarily thinking about it; see Michael Polanyi, *The Tacit Dimension* (New York: Doubleday-Anchor, 1966), 9–10, passim.
- ⁴Our analysis is restricted to finding conditions for the *possibility* of scientific endeavor. We are not trying to determine historical conditions that may have caused or impelled certain individuals to pursue science within the context of those conditions. The answer to that question is likely to vary from individual to individual. Here we focus on the common cultural frame that made scientific endeavor possible—a necessary though not sufficient condition for such endeavor.
- ⁵Chet Raymo, Skeptics and True Believers: The Exhilarating Connection Between Science and Religion (New York: MJF Books, 1998), 2–4.
- ⁶I have borrowed the term, "creationist tradition," from Richard C. Dales, "A Twelfth-Century Concept of the Natural Order," *Viator* 9 (1978): 191–2. This historic "creationist tradition" is a composite of beliefs that supports scientific endeavor and is not to be confused with "creation science."
- ⁷Lü Shi Chun Qiu V.2; *The Annals of Lü Buwei*, trans. John Knoblock and Jeffrey Riegel (Stanford: Stanford University Press, 2000), 136–9; cf. Derk Bodde, *Chinese Thought, Society, and Science: The Intellectual and Social Background of Science and Technology in Pre-Modern China* (Honolulu: University of Hawaii Press, 1991), 335–6. Bodde's essay (first published in 1979) describes this and a number of similar texts from ancient China. Other ancient Chinese texts like the famous Chuang Tzu (Zhuang zi, chaps 2, 5) emphasize the other side of the dialectic – the difference between conventional human understanding and the laws of Heaven.
- ⁸Qur'an Sûrah 13:2 ("each running to an appointed term"); 36:37–8 ("each in an orbit"); 41:12 ("in each heaven its mandate"); English translation (ET) in *The Meaning of the Glorious Koran*, trans. Mohammed Marmaduke Pickthall (New York: New American Library, 1953), 182, 316, 341.
- ⁹The thirteenth-century Syrian physician, Ibn al-Nafîs developed a theory of the circulation of blood very similar to the later ideas of William Harvey. His treatise was preserved by a Cairo hospital, but was forgotten and remained unknown until its modern rediscovery. In the sixteenth century, Taqî al Dîn wrote books on astronomy, optics, and mechanical clocks. As court astronomer to the Sultan, he was able to build an observatory in Istanbul (1577) comparable to that of Tycho Brahe in Denmark. Al Dîn's observatory was later destroyed on the recommendation of the chief Mufti and was never rebuilt; Bernard Lewis, *What Went Wrong? The Clash*

Between Islam and Modernity in the Middle East (New York: Oxford University Press, 2002), 79–81.

¹⁰The word "scientist" did not come into use until the nineteenth century when various sciences became specialized and professionalized. Before that time, most scientists thought of themselves as philosophers or "natural philosophers." Using the term "scientist" for earlier centuries is technically anachronistic, but necessary in order to convey a sense of continuity of scientific endeavor over time.

¹¹It is difficult to adjudicate competing claims for the earliest sustainable research institutes, but the idea was first advocated by seventeenth-century Europeans like Francis Bacon, Jan Comenius, and Samuel Hartlib.

¹²See Kaiser, *Creational Theology and the History of Physical Science: The Creationist Tradition from Basil to Bohr* (Leiden: E. J. Brill, 1997), 47–59, on the development of conflict in the creationist tradition of Western Europe.

¹³See the excellent studies by David Lindberg and Edward Larsen in *When Science and Christianity Meet*, ed. David C. Lindberg and Ronald L. Numbers (Chicago: University of Chicago Press, 2003).

¹⁴E.g., David C. Lindberg and Ronald L. Numbers, "Beyond War and Peace: A Reappraisal of the Encounter between Christianity and Science," *Perspectives on Science and Christian Faith* 39 (Sept. 1987): 140–9.

¹⁵E.g., Kepler's letter to Galileo, Aug. 1597; Carola Baumgardt, *Johannes Kepler: Life and Letters* (New York: Philosophical Library, 1951), 40–2.

¹⁶Baumgardt, Johannes Kepler: Life and Letters, frontpiece.

¹⁷Latin and English texts are found in Johannes Kepler, *Mysterium Cosmographicum: The Secret of the Universe*, trans. A. M. Duncan (New York: Abaris Books, 1981), 48–9. The full Latin title was *Prodromus Dissertationum Cosmographicarum Continens Mysterium Cosmographicum* ("A Preview of Cosmographical Dissertations Containing the Mystery of the Cosmos"). A second, annotated edition was published in 1621.

¹⁸For Kepler's other attempts to explain the arrangement of the planets, see Fernand Hallyn, *The Poetic Structure of the World: Copernicus and Kepler*, trans. from French by D. M. Leslie (New York: Zone Books, 1990), 187–9.

¹⁹Kepler, *Mysterium Cosmographicum*, Preface to the Reader, 63.

²⁰Christopher B. Kaiser, *Creation and the History of Science* (Grand Rapids: Eerdmans, 1991); Kaiser, *Creational Theology and the History of Physical Science*.

²¹Kepler did express the hope that his discoveries would convince some philosophers that the world was created and ordered by God, but his own belief was rooted in his religious heritage; cf. Kepler's letter to Baron von Herberstein, 15 May 1596; in Baumgardt, *Johannes Kepler: Life and Letters*, 33–5.

²²Calculus was not invented until the time of Newton and Leibniz. Kepler did his calculations with logarithms.

²³Kepler's Astronomia Nova was written in 1605–1606 and published in 1609. For a good, brief description of Kepler's long process of discovery, see. A. C. Crombie, Augustine to Galileo: The History of Science AD 400–1650, 2 vols., 2d ed. (Oxford: Heinemann, 1959), 2:188–90.

²⁴Howard Margolis coins the term "around-the-corner inquiry" for insights like Kepler's in order to differentiate it from direct inference; Margolis, It Started with Copernicus: How Turning the World Inside Out Led to the Scientific Revolution (New York: McGraw-Hill, 2002), 126–7, 160–1.

²⁵Isaac Newton, *Philosophiae Naturalis Principia Mathematica* ("Mathematical Principles of Natural Philosophy").

²⁶For details, see Crombie, *Augustine to Galileo*, and Arthur Koestler, *The Sleepwalkers: A History of Man's Changing Vision of the Universe* (New York: Macmillan, 1959), 213–22.

²⁷The Latin title is *Harmonice Mundi* (1619), which is sometimes translated "Harmony of the World."

²⁸Drawn by Christopher Leibfried, Tübingen, 1597; Kepler, *Mysterium Cosmographicum*, Plate 3; see p. 228 for a listing of the planets and regular solids. ²⁹Kepler, Harmonice Mundi IV.1; Johannes Kepler, Gesammelte Werke, 20 vols., ed. Walther von Dyck, Max Caspar, et al. (Munich: Becksche Verlagsbuchhandlung, 1937-1988), 6:223, lines 32-4; ET from Johannes Kepler, The Harmony of the World, trans. E. J. Aiton, A. M. Duncan, and J. V. Field (Philadelphia: American Philosophical Society, 1997), 304 (slightly modified). The same idea is found in Kepler's defense of Galileo, Dissertatio cum Nuncio Sidereo; Gesammelte Werke, 4:308. In the context of the passage cited from Harmonice Mundi IV.1, Kepler identified geometry as one of the attributes of the divine being (quid enim in Deo quod not sit Ipse Deus, "for what is in God that was not God himself?"). This idea was already found in Augustine (e.g., On Genesis Literally IV.3.7), but Kepler was commenting here on the (recently read) Neoplatonic ideas of Proclus, which he had interpreted in accordance with what is "known to Christians" like Augustine concerning the doctrine of creation; cf. Kepler, Harmony of the World, 299, 303, 493. See the marginal note in Harmonice Mundi I, Proposition 45, and the discussion of Axiom 7 in Book III; Gesammelte Werke, 6:47-9; ET in Kepler, Harmony of the World, 74, 146-7.

³⁰Proclus was a sixth-century Neoplatonist who taught that geometrical structures like the sphere were inscribed on the human soul by the cosmological Mind or Intellect (Nous); Proclus, *A Commentary on the First Book of Euclid's Elements*, trans. Glenn R. Morrow (Princeton: Princeton University Press, 1970), 14. The Platonic explanation for the adaptation of the human psyche to the deep structures of the universe is rather different from the evolutionary explanation given in Chapter 2. Our concern in this chapter is with the culture of belief rather than with the anthropological question of origins.

³¹As Kepler explained in a Letter to Johann Georg Brengger, 5 April 1608, the human soul (or spirit) was formed out of celestial (spiritual) substance and then "illuminated and instructed by a ray out of God's image"; Baumgardt, *Johannes Kepler: Life and Letters*, 79; cf. Philo, *De Opificio Mund*, 146 ("a copy or fragment or ray of that blessed nature"). The interpretation of the "heavens" in Genesis 1:1 as unformed spiritual substance goes back as far as Augustine, *Confessions*, XII.17.25; XIII.2.2–3.

³²Gerald Holton, *Thematic Origins of Scientific Thought: Kepler to Einstein* (Cambridge, MA: Harvard University Press, 1973), 84; rev. ed. (1988), 68.

³³Letter to Michael Mästlin, 9 April 1597; *Gesammelte Werke*, 13:27; ET from Holton, *Thematic Origins of Scientific Thought*, 84; rev. ed., 68 (modified). Mästlin had helped to arrange the publication of Kepler's *Mysterium Cosmographicum* (1596), for which he also provided a preface and an appendix.

³⁴In Chapter 2, I argued for an evolutionary explanation for both of these adaptations.

³⁵Gerald Holton suggests that Kepler had two different gods: one biblical and the other Pythagorean; Holton, *Thematic Origins of Scientific Thought*, 86; rev. ed., 70. However, the idea that God had created everything "according to the norm of quantity" was already in Kepler's Bible in texts like Wisdom 11:20 and will be discussed below.

³⁶Letter to Johannes Georg Herwart von Hohenburg, 9/10 April 1599; *Gesammelte Werke*, 13:309, letter no. 117, lines 174–9; ET in Baumgardt, *Johannes Kepler: Life and Letters*, 50. As Chancellor of Bavaria, von Hohenburg was able to help Kepler establish connections at the Imperial Court in Prague. He was also a mathematician and, though a Catholic, had studied under Mästlin; Baumgardt, *Johannes Kepler: Life and Letters*, 57–9. Kepler shares his ideas about God and creation with Herwart as if the two of them remembered them from their teacher.

³⁷For a detailed treatment of Kepler's Lutheran background, see Peter Barker and Bernard R. Goldstein, "Theological Foundations of Kepler's Astronomy," in John Hedley Brooke, Margaret J. Osler, and Jitse Van der Meer, eds, *Science in Theistic Contexts: Cognitive Dimensions (Osiris* 16, Chicago: University of Chicago Press, 2001), 88–113.

³⁸Martin Luther, Lectures on Genesis, Chapters 1–5, in Jaroslav Pelikan and Helmut T. Lehmann, eds., Luther's Works: American Edition,

55 vols. (St. Louis and Philadelphia: Concordia and Fortress Press, 1955-1976), 1:66.

³⁹Luther's Works, 1:45–6.

⁴⁰Melanchthon, On Christian Doctrine: Loci Communes 1555, ed. Clyde L. Manschrek (New York: Oxford University Press, 1965), 71.

⁴¹Robert S. Westman, "The Melanchthon Circle, Rheticus, and the Wittenberg Interpretation of the Copernican Theory," Isis 66 (June 1975): 165-93; E. J. Aiton, Introduction to Johannes Kepler, Mysterium Cosmographicum: The Secret of the Universe, trans. A. M. Duncan (New York: Abaris Books, 1981), 23.

⁴²For specifics, see Kaiser, Creational Theology and the History of Physical Science.

⁴³Paul Davies is currently Visiting Professor of Physics at Imperial College London, Adjunct Professor of Physics at the University of Queensland and Adjunct Professor of Natural Philosophy in the Australian Centre for Astrobiology at Macquarie University, Sydney; www.abc.net.au/science/morebigquestions/davies.htm.

⁴⁴Paul Davies, The Mind of God: The Scientific Basis for a Rational World (New York: Simon & Schuster, 1992), 20.

⁴⁵In another of his writings, Paul Davies states that the general quest of modern science has historical roots in a theological worldview, but he does not specify creational beliefs; Davies, Are We Alone? Philosophical Implications of the Discovery of Extraterrestrial Life (Harmondsworth: Penguin, 1995), 138.

⁴⁶Henry Margenau, Open Vistas: Philosophical Perspectives of Modern Science (New Haven: Yale University Press, 1961), 73, 75. For Margenau, the "newness" of this faith was relative to the prior ideology of logical positivism, which held that science was independent of metaphysics and dealt only with the empirically verifiable. As we shall argue, the "new faith" of which Margenau spoke had deep historical roots.

⁴⁷Margenau, Open Vistas, 75. William G. Pollard was another physicist-philosopher who wrote in 1961 to point out the importance of "a firm and unshakable faith in the ultimate intelligibility of the chaotic torrent of phenomena in terms of underlying laws and universal principles"; Pollard, Physicist and Christian: A Dialogue between Two Communities (New York: Seabury Press, 1961), 14-16. Pollard and Margenau were the two science-writers who most influenced me in my studies as a student of science.

⁴⁸Lewis Wolpert, Six Impossible Things Before Breakfast: The Evolutionary Origins of Belief (London: Faber & Faber, 2006), based on Lewis Carroll, Through the Looking-Glass and What Alice Found There (C. L. Dodgson, 1871).

⁴⁹Margenau, Open Vistas, 76.

⁵⁰Margenau, Open Vistas, 74.

- ⁵¹The following discussion is based on my essay, "Humanity in an Intelligible Cosmos" (2001).
- 52 Einstein, "Scientific Truth" (1929), in Einstein, The World As I See It (London: John Lane, 1935), 131; also in Einstein, Ideas and Opinions (London: Alvin Redman, 1954), 262.

⁵³Interestingly, Einstein did not view the new science of quantum theory as "rational" in this sense due to the seemingly contradictory properties of photons; see Marcus Chown, "Einstein's Rio Requiem," New Scientist 181 (6 March 2004), 50-1.

⁵⁴Einstein, "Principles of Scientific Research" (1918); "Inaugural Address to the Prussian Academy of Sciences" (1914); "The Method of Theoretical Physics" (1933), in Einstein, World As I See, 125-6, 128, 136; also in Einstein, Ideas and Opinions, 221, 226-7, 274.

55Einstein, "Principles of Scientific Research" (1918), in Einstein, The World As I See It, 125-6; also in Einstein, Ideas and Opinions, 226-7.

⁵⁶Einstein, "Physics and Reality" (1936), in Einstein, Out of My Later Years (New York: Philosophical Library, 1950), 61; also in Einstein, Ideas and Opinions, 292. By "world of our sense experiences," Einstein meant primarily the world of empirical scientific discovery; cf. "The Method of Theoretical Physics" (1933), in Einstein, The World As I See It, 133; also in Einstein, Ideas and Opinions, 271.

⁵⁷E.g., Einstein, "The Fundaments of Theoretical Physics" (1940); "Message to the Italian Society for the Advancement of Science"

(1950), in Einstein, Ideas and Opinions, 324, 357; Einstein, "Autobiographical Notes," in Paul Arthur Schilpp, ed., Albert Einstein: Philosopher-Scientist (LaSalle, IL: Open Court, 1949), 63.

⁵⁸Einstein, "The Religiousness of Science" (1934 or earlier); "Scientific Truth" (1929), in Einstein, The World As I See It, 28, 131; Einstein, Ideas and Opinions, 40, 262

59Einstein, "Science and Religion II" (1941), in Einstein, Out of My Later Years, 29; also in Einstein, Ideas and Opinions, 49. Cf. Einstein's 1952 letter to Beatrice F. of San Francisco:

I am imbued with the consciousness of the insufficiency of the human mind to understand deeply the harmony of the universe which we try to formulate as "laws of nature." It is this consciousness and humility I miss in the Freethinker mentality (Letter from Einstein Archive, quoted in Max Jammer, Einstein and Religion: Physics and Theology [Princeton: Princeton University Press, 1999], 121-2).

Einstein did not explain exactly what he meant here by the limitations of the human mind. Elsewhere he does state that physics deals with only a small part of nature, excluding all its more subtle and complex aspects; Einstein's Preface to Max Planck, Where Is Science Going? trans. James Murphy (London: Allen & Unwin, 1933), 11. Presumably he meant those aspects of nature that emerge in human history, which would include the emergence of the very intelligence that physicists rely on in their work. That same year he spoke of "the theorist's hope of grasping the real in all its depth"; Einstein, "The Method of Theoretical Physics" (1933), in Einstein, The World As I See It, 138; also in Einstein, Ideas and Opinions, 275.

60Einstein, "Science and Religion II" (1941), in Einstein, Out of My Later Years, 26; also in Einstein, Ideas and Opinions, 46. Cf. Einstein's reference to "the truly religions conviction that this universe of ours is something perfect and susceptible to the rational striving for knowledge"; "Religion and Science: Irreconcilable?" in Einstein, Ideas and Opinions, 52.

⁶¹On Maxwell's faith and its impact on Einstein, see my Creational Theology and the History of Physical Science, 379-99.

62Einstein, "Religion and Science" (1930), in Einstein, The World As I See It, 27; also in Einstein, Ideas and Opinions, 39-40.

63E.g., Einstein, World As I See It, 25, 28; cf. Jammer, Einstein and

Religion, 47–50, 74–5. ⁶⁴Einstein, "Religion and Science" (1930); "Johannes Kepler"; "Religion and Science: Irreconcilable?" (1948), in Einstein, The World As I See It, 25-27, 141-2; also in Einstein, Ideas and Opinions, 38-40, 52. Here Einstein also cited Spinoza and Schopenhauer's descriptions of Buddhism.

⁶⁵The phrase, "thick description," is borrowed from the work of Clifford Geertz, The Interpretation of Cultures: Selected Essays (New York: Basic Books, 1973), 9-13, 17.

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