# The Christian Origin of Science

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The First Coyne Lecture on Theology and Science
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# The Christian Origin of Science

Viewed in the widest historical perspective, the explosive development of science in seventeenth-century Europe is one of the most astonishing events in the whole of human history. It makes our civilization unlike any other. For the first time people all over the world are joined together by rapid communications, easy travel, and extensive trade. Why did this understanding of the detailed structure of the world that we call science develop and come to maturity just when and where it did? This is a question that can lead us to the heart of the relation between science and the Christian basis of our civilization.

It is usual to discuss the relation of science to religion as if they are two independent activities. We can then compare and contrast their objectives, their modes of procedure, and the status of their conclusions. This is not without value, but it presupposes that they are two independent activities that somehow have to be related to each other. This directs attention away from the central point that is essential for the understanding of their relationship, namely that

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when seen in the perspective of history there is an organic connection between them. Science as we know it is based on certain definite beliefs about the world, and these beliefs have their origin in the theology of Christian Europe.

If we look at the great civilizations of the past, in China and India, in Babylon and Egypt, in Greece and Rome, we frequently find well-developed social structures, magnificent artistic and architectural achievements, imperishable drama and philosophy, but nothing remotely equivalent to modern science. We find great skill in the working of wood and metal, ingenious mechanical contrivances, and perceptive philosophical speculations about the world, but not the detailed quantitative understanding of matter, from quarks to galaxies, expressed as the solution of a few differential equations, that is the hallmark of the more developed areas of modern science.

Most of the great civilizations of the past were able to provide all the material requirements for the growth of science. There was a leisured class, technical skills, and systems of writing and mathematics. Obviously this by itself is not enough. What was lacking was the attitude of mind toward the material world that is the essential precondition of science, and in some cases a social structure that allows new ideas to flourish.

What do we have to believe before we can hope to become a scientist? We must believe that the world is in some sense good, so that it is worthy of careful study. We must believe that it is orderly and rational, so that what we find out one day will still be true on the next day. We must believe that this order is open to the human mind, for otherwise there would be no point in trying to find it. We must believe that this order is not a necessary order that could be found out by pure thought like the truths of mathematics, but is rather a contingent or dependent order that can only be found by making experiments.

In addition to these beliefs about the world itself, the development of science depends on moral convictions such as the obligation to freely share any knowledge that is gained. Furthermore, once it

becomes clear that scientific understanding can be applied to grow more food and to cure diseases then its further development is encouraged if we believe that we should do these things to help all people.

These beliefs may seem obvious to us, but in the context of human history they are very special. They are not found in the ancient civilizations, and that is why science in the modern sense never developed among them. In some cases, particularly in ancient Greece, an impressive start was made by a few individuals of genius, but they lacked the support of a coherent set of beliefs shared by the whole community, and it never became a self-sustaining enterprise.

Why were these beliefs found in Christian Europe? Is there any connection between the medieval theology that formed the mind of Europe in the critical centuries before the birth of science? In each case we find that there is indeed such a connection. In order to see that this is so we have to look in more detail at the historical development of science.

## *The Origin of Science*

Our present scientific and technical knowledge has been attained by a long, hard, and winding road from the astronomical observations of the Babylonians to the quantum theory and supercomputers of today. Initially, science was not distinguished from philosophy and its roots are to be found in the early struggles to make sense of the world. Before answers can be found, we must ask the right questions. What methods should we use to understand nature? How can we know that our answers are true? Why do things change? Is there an unchangeable reality beneath the changes that surround us? Over the centuries these questions have been answered in different ways under the influence of the surrounding culture.

It was extremely difficult to get started. The early Ionian philosophers made some tentative speculations, but the first really systematic attempt was made by Aristotle. He took all knowledge for his

province and proposed a vast rational structure embracing all fields of activity from mathematics, physics, and biology to politics, art, and music. He was an exceptionally acute observer, and many of his biological descriptions and discoveries were not surpassed until the invention of the microscope about two millennia later.

Aristotle was primarily concerned with the general principles of nature and with the qualitative relations among things, and not with precise quantitative analysis. He recognized that some natural phenomena such as optics and musical harmonies could be described mathematically, but he distinguished this from mathematics on the one hand and natural philosophy on the other. Aristotle considered the world as an organism acting for a purpose. Every material body has a natural place and always moves toward that place. This may be seen most clearly in his discussion of motion, the most fundamental phenomenon that lies at the basis of physics and hence of all science. He distinguished between two types of natural motion, the circular motion characteristic of the celestial bodies, and linear motion characteristic of bodies on the earth. The celestial realm is changeless and incorruptible and the planets must move in circular orbits because the circle is the most perfect curve. On the earth, bodies strive to reach their natural place, fire going upwards and heavy bodies downwards. Their rate of fall depends on their weights, as heavy bodies strive more strongly to reach their natural places; a body of a certain weight thus falls twice as fast as one of half its weight. Thus although Aristotle maintained that all knowledge comes to us through the senses, he often preferred his deductions to the simplest observations. In this case a thought experiment suffices, as according to him two equal weights joined by a light rod should fall at twice the speed of unconnected weights.

Aristotle analyzed the concepts of space, time, and motion, and came to the conclusion that the world is eternal. He also believed that time is cyclic, so that after a long time everything is repeated again and again, without end.

The Aristotelian world picture was a logically coherent structure that served as a framework for thinking for almost two thousand years. By its emphasis on purpose, a concept that has no place in physics, its overly optimistic belief that it is possible to intuit the structure of the world, and its lack of understanding of the importance of quantitative measurement, it prevented the development of genuine science. Other Greeks, notably Archimedes and Euclid, made fundamental advances in geometry and the analysis of natural phenomena, but in spite of the heroic beginning Greek science never developed into a self-sustaining enterprise.

To sum up, Aristotle believed in the eternity of the world, in a cyclic universe, and in a world of purpose, even in material things. He also believed that celestial matter, the world of the stars and planets, is incorruptible, unlike terrestrial matter that can undergo change. These beliefs prevented the development of science for two thousand years. Their stranglehold had to be broken before science could develop into its modern form.

A new beginning, a fresh style of scientific thinking, was made possible by the Judeo-Christian vision of the world. The God of the Hebrews is very different from the God of Plato or the Prime Mover of Aristotle. In sharp contrast, the God of the Hebrews freely created a world completely distinct from Himself, and His actions are inscrutable to men unless He freely chooses to reveal His plans.

The book of Genesis bears witness to the Hebrew belief in a transcendent Creator from its opening phrases: "In the beginning God created the heavens and the earth." "And God saw all that He had made, and indeed it was very good" (Gen. 1:1; 1:31). In contrast to the confused creation myths of the surrounding nations, the creation story in Genesis has a clear logical structure, expressed in poetic form. It clearly expresses belief in the absolute sovereignty, rationality, and benevolence of God who brings everything into being by His command and communicates His own goodness to them. Although not expressed in modern language, it contains the essential beliefs about the world that must be held if science is to flourish.

The earliest psalms tell us how God made the world and prepared it for man: He sets the heavens, the moon, and the stars in their places and makes man the ruler over his works, ordering everything "in measure, number and weight" (Wis. 11:20). In His reply to Job, Yahweh asks

> "Where were you when I laid the earth's foundations?
> Tell me, since you are so well-informed!
> Who decided the dimensions of it, do you know?
> Or who stretched the measuring line across it?"

God is all-powerful, and He alone is to be worshiped. The animist beliefs of the Egyptians and the Babylonians, the gods of the forest grove, the belief in the divine earth-mother, are all totally rejected.

Nothing comes into being, nothing remains in being, without being loved and willed by God:

> "You made all that exists; you hold nothing
> of what you have made in abhorrence,
> For had you hated anything you would not have formed it.
> And how, had you not willed it, could a thing persist?
> how be conserved if not called forth by you?"
>
> (Wis. 11:24–26).

The heroic mother of the seven martyred brothers in Maccabees likewise expressed her belief in creation when she exhorted her sons to stand firm, saying to them: "I do not know how you appeared in my womb; it was not I who endowed you with breath and life. I had not the shaping of your every part. It is the creator of the world, ordaining the process of man's birth and presiding over the origin of things, who in his mercy will most surely give you back both breath and life, seeing that you now despise your own existence for the sake of his laws." When it came to the last son, Antiochus tried to persuade him to abandon the traditions of his ancestors, and appealed

to his mother to advise the young man to save his life. She finally agreed to persuade her son, but she fooled the cruel tyrant with the words: "I implore you, my child, observe heaven and earth, consider all that is in them, and acknowledge that God made them out of what did not exist, and mankind comes to being in the same way. Do not fear this executioner, but prove yourself worthy of your brothers, and make death welcome, so that in the day of mercy I may receive you back in your brothers' company."

The faithfulness of God to Israel is compared with the reliability of natural phenomena (Jer. 31:35).

> "Your word, O Lord, for ever
> Stands firm in the heaven.
> Your truth lasts from age to age
> like the earth your creator." (Ps. 119:89).

The order and stability of natural phenomena is taken for granted with the same quiet certainty as shown by the mother of the seven brothers:

> God's laws are permanently valid, and endure for ever:
> "When God created His works in the beginning
> he allotted them their portions as soon as they were made
> he determined his works for all time
> from their beginnings to their distant future.
> They know neither hunger nor weariness,
> and they never desert their duties.
> None has jostled ever his neighbour,
> they will never disobey his word." (Sir. 16:24–26)

Matter is entirely passive and it consequently endures, obedient to God's will. It is a perfect model for us.

In all these accounts of creation there is no distinction between the heavens and the earth, between the celestial and the terrestrial realms; both are made by God and are totally subject to His laws.

Thus according to Judeo-Christian beliefs the world is the free creation of God from nothing. The structure of the world cannot therefore be deduced from first principles; we have to look at it, to make observations and experiments to find out how God made it. This reinforces the Aristotelian principle that all knowledge comes through the senses, but requires that it be situated within a wider set of beliefs concerning the nature of the world that is implicit in the doctrine of creation. Aristotle's natural theology is thus transformed into the Christian notion of divine providence: God is not simply the Prime Mover or First Cause, He is the cause of the very existence of the world and its continuance in being.

Thus we know that the world is rational because it was made and is kept in being by a rational God. It is contingent because it depends on the Divine Fiat: God could have chosen to make the world in a different way. There is here a delicate balance between the rationality and the freedom of God: tip the balance one way or the other and you have a belief in a necessary world or in a chaotic world, both inimical to the growth of science. Finally, we are assured that the enterprise is a practicable one, that the world is open to the human mind, because God charged us to have dominion over it, and He does not command the impossible: "'Be fruitful, multiply, fill the earth and conquer it. Be masters of the fishes of the sea, the birds of heaven and all living animals on the earth'" (Gen. 1:28). Whatever wisdom we acquire, we must pass on to others: "What I have learned without self-interest, I pass on without reserve; I do not intend to hide her riches. For she is an inexhaustible treasure to men, and those who acquire it win God's friendship" (Wis. 7:13).

The first study of the effect of the Hebrew theology of creation on Greek philosophy was made in the first century B.C. by Philo Judaeus of Alexandria. He accepted the Greek idea of unchangeable causality, but not the modes of causality proposed by Plato, Aristotle, and the Stoics. Following Scripture, he argued that "God did not act as Aristotle had maintained as an essentially passive first cause co-

eternal with the world emanating by necessity from divine reason, that God did not make the world out of pre-existing matter as Plato proposed in the *Timaeus*, that God was neither material nor in the world as supposed by the Stoics, and that God is in no way necessitated, but that he had acted with entirely free omnipotence in creating *ex nihilo* a world separate from himself" (Crombie, 294). He used the word *logos* to denote the rational pattern on which God modeled His creation, the immutable laws governing the world that show God's power within it. They are often obscure to us, but they lie behind the motions of the stars and all natural phenomena. God is the absolute Lord of the universe; He has laid down its laws but can overrule them at will.

### *The Early Christian Centuries*

The birth of Christ further ennobled the matter of the universe, and his teaching reinforced and enhanced the teaching contained in the Old Testament. The debilitating belief in a cyclic universe, held in all ancient cultures, was decisively broken by the Christian belief in the uniqueness of the Incarnation. Henceforth history was no longer an infinite series of dreary cycles, but a linear story with a beginning and an end. Inherent in Christ's teaching is a set of beliefs about the world that eventually led to the first viable birth of science in the High Middle Ages, and to its subsequent flowering in the Renaissance.

In the early Christian centuries several philosophers examined the cosmology of creation in the context of Christian theology. In the third century A.D. Lactantius rejected the Stoic belief that nature is animate and that God is within the world, and also the Epicurean belief that the world is simply the product of chance, without any providential design. He emphasized that God with infinite power created the world out of nothing, so that he is absolutely separate from His creation. Nature is designed by God ultimately for the benefit of man, and has no power of its own that does not come from

God. This implies that nature is an inanimate mechanism operating according to fixed laws. In the fourth century A.D. Basil of Cappodocia insisted, contrary to Plato, Aristotle, and other Greek philosophers, that nature is not animate, nor is it a living thing endowed with senses. When plants and animals grow, they do so following God's command and in accord with His laws.

The Christian beliefs concerning creation emphasize not only that the universe was created by God out of nothing and in time, but that the universe is totally dependent on God and totally distinct from God. The universe at any instant is sustained in being by God, and without this sustaining power it would immediately lapse into nothingness.

At that time there were passionate debates about the nature of Christ, and heresies abounded. To define the true nature of Christ was the task of a series of Councils of the Church, and of these, the Council of Nicea (325) formulated the creed that is widely held today:

> *"Credo in unum Deum, Patrem omnipotentem, factorem coeli et terrae, visibilium omnium et invisibilium. Et in unum Dominum Jesum Christum, Filium Dei unigenitum, et ex Patre natum ante omnia saecula. Deum de Deo, Lumen de Luminae, Deum verum de Deo vero, genitum non factum, consubstantialem Patri; per quem omnia facta sunt."*

It is easy to recite these hallowed phrases without fully realizing their impact, and still more their importance for science. The beginning of the Nicene creed asserts the creation of the universe by God: "*Factorem coeli et terrae*." One of the early heresies was pantheism that failed to distinguish between God and His creation, holding that it is in some way part of God. In the Greco-Roman world, the universe was thought of as an emanation from a divine principle that is not distinguished from the universe. Pantheism is explicitly excluded by the Nicene creed when it says that Christ is

the only-begotten Son of God. Christ is begotten, not made. Only Christ was begotten and thus shared in the substance of God; the universe was made, not begotten. ("*Et in unum Dominum Jesum Christum, Filium Dei unigenitum . . . Genitum, non factum.*") Since pantheism was one of the beliefs preventing the rise of science in all ancient cultures, the Nicene creed prepared the way for the one viable birth of science in human history.

Many ancient cosmologies held that the world is a battleground between the spirits of good and evil. This dualism is inimical to science because it makes the world unpredictable. Dualism is excluded by the Nicene creed when it says that all creation takes place through Christ ("*per quem omnia facta sunt*").

In his Epistle to the Colossians, St. Paul says that in Christ all things took their being, and were all created through him and in him (Col. 1:15). He stressed Christ as the divine *logos* and the consequence that the creation must be fully logical and orderly. He referred to creation out of nothing when he praises God "who restores the dead to life and calls into being those things which had not been" (Rom. 4:17) and promises that through Christ they would understand "the breadth, the height and the depth" (Eph. 3:18).

Inherent in the Christian doctrine of creation is the belief that God freely chose to create the universe. He was not in any way constrained either to create or not to create it in the way that He did. It is therefore not a necessary universe in the sense that it had to be created or could not have been created otherwise. There is therefore no possibility of finding out about the universe by pure thought or by a priori reasoning. We can only hope to understand it by studying it and by making experiments. Thus the Christian doctrine of creation encouraged the experimental method, essential for the development of science.

The theology of St. Augustine of Hippo (354–430) encouraged the systematic study of the natural world, since he believed that its sacramental nature is symbolic of spiritual truths. He was a com-

pulsive observer of natural phenomena, always on the lookout for anything that gives even a fleeting glimpse of the Reason behind all things. The laws of nature are objective and inexorable, unalterable by us but not by God. He encouraged the study of nature and the search for its laws, to read the book of nature: "Look above and below, note, read. God, whom you want to discover, did not make the letters with ink; he put in front of your eyes the things that he made." Following Plato, he recognized the importance of mathematics, saying that the laws of nature are the laws of numbers. There is a rational pattern in nature, that follows from the unchanging laws that govern its development through time. He was interested in nature primarily because it reveals God to the attentive observer. His philosophical reflections on the nature of time are still quoted as among the most profound ever written.

In the early sixth century John Philoponus, a Christian Platonist who lived in Alexandria, wrote extensively on the material world, showing the influence of Christian beliefs on those of the surrounding pagan world, particularly those derived from ancient Greece. He commented extensively on Aristotle, whom he greatly admired, but when the teaching of Aristotle was contrary to Christian belief he did not hesitate to differ from it. This was particularly important in his commentary on Aristotle's physics where he said, contrary to Aristotle, that all bodies would fall in a vacuum at the same speed, irrespective of their weight, and that projectiles move through the air not due to the motion of the air but because they were initially given a certain quantity of motion. This is a remarkable anticipation of ideas normally associated with Galileo, and shows a decisive break with Aristotelian physics. He was not the first writer in antiquity to break with Aristotle, but he did so more clearly and decisively.

The connection between his rejection of Aristotelian ideas and his Christian beliefs is to be found in the doctrine of creation. Addressing the question of motion, he asked "could not the sun, moon and the stars be given by God, their Creator, a certain kinetic

force, in the same way as heavy and light things were given their trend to move?" He also believed that the stars are not made of the ether but of ordinary matter, thus rejecting Aristotle's distinction between celestial and terrestrial matter.

This shows very clearly that the Christian beliefs about the world are incompatible with the Aristotelian views on the divinity of celestial matter and the eternity of motion. It was thus inevitable that the spread of Christianity should lead eventually to the destruction of Aristotelian physics, thus opening the way to modern science. This is not to say, however, that Christian beliefs give any specific guidelines for the development of science, but the removal of obstacles is by itself no small service.

Philoponus was also the first to say that Genesis was written for spiritual and not for scientific instruction, a wise statement that was too far in advance of its time to be congenial to contemporary theologians. This theological boldness perhaps explains why Philoponus's ideas did not lead to further scientific developments. His ideas on motion are remarkably similar to those of Buridan and Oresme in the High Middle Ages, which did succeed in initiating the scientific enterprise. To be fruitful, ideas have not only to be right, but they need to fall on fertile ground, in this case a society sufficiently developed to make full use of them, and this was lacking for Philoponus. There has been some speculation about whether the ideas of Philoponus were known to Buridan, but nothing seems to be established definitely on this question.

We are now on the threshold of the decisive breakthrough that led eventually to the rise of modern science.

### *The High Middle Ages*

Early in the twelfth century, Hugh of St. Victor saw the study of the natural world as a twofold process, first the ascent of reason to the purely spiritual and then a descent to examine in its light the infor-

mation provided by the senses. In so doing he expressed the mathematical rationalism of Plato and inspired his contemporaries William of Conches, Thierry of Chartres, and Adelard of Bath, for whom reality was autonomous nature to be grasped by reason.

In the twelfth and thirteenth centuries there was a remarkable flowering of creativity in many areas of human activity. At the sociological level, this was largely due to the new concept of treating a group of people as a separate legal entity. This enabled them to act with considerable freedom, but always subject to the law. It came about as a result of what has been called the Papal revolution, by which the Church asserted its freedom from the civil authorities. Previously, it was usual for clerical appointments to be made by the civil authorities, but now the Church insisted that it alone had the authority to do this. This established the Church as a separate legal entity and put constraints on the power of the civil authorities. The most significant result was the creation of a separate legal system with its own area of jurisdiction. Once this idea was established, both Church and State became federations of many corporations, each with a measure of autonomy. Among these were cities, the first universities, the legal and medical professions, banks and business organizations, and later on, the scientific community itself.

In the High Middle Ages, many universities were founded by the Church to provide higher education for those educated in the monastic schools, to train future clerics and to facilitate the spread of learning. It was in these universities that the decisive breakthrough that led to the rise of modern science took place. The works of Aristotle and the other Greek philosophers were translated into Latin and were used by theologians to express the truths of the faith in more precise language, and by philosophers to refine their view of the natural world.

So great was the prestige of Aristotle that the philosophers of the medieval schools taught by commenting on his texts. Some of Aris-

totle's teaching, however, was inconsistent with the Christian faith, and the philosophers did not hesitate to differ from Aristotle when it seemed necessary. In 1215, the Fourth Lateran Council decreed that all creation, spiritual and material, took place out of nothing and in time. This is directly contrary to Aristotle's belief in the eternity of the world. There was intense discussion on a variety of topics, notably concerning the creation of the world and the motion of bodies. In 1277, the bishop of Paris, Etienne Tempier, found it necessary to condemn 219 philosophical propositions as contrary to the Christian belief. His main purpose was to defend God's absolute power against any attempt by the Aristotelian philosophers to set limits to it. Several of the condemned propositions set limits to God's power, saying, for instance, that He cannot make more than one world or move the world so as to produce a vacuum. Tempier thus reasserted the belief that God can freely create any world, just as He chooses. This was a turning point in the history of thought, as it liberated philosophers from bondage to Aristotle and channeled philosophical speculations about motion in a direction that led eventually to the destruction of Aristotelian physics, thus opening the way to modern science.

The theology of divine omnipotence had important consequences for the development of science as a result of Aquinas's distinction between God's absolute and ordained powers. God always has absolute power over all things, but he endows the natural world with specific natures, according to His plan for creation. These normally determine the behavior of natural phenomena. It thus becomes a reasonable activity to try to find out about the world. Normally, by virtue of God's ordained power, the natural world strictly follows God's laws, and yet this does not prevent God from doing whatever He chooses by virtue of His absolute power. This reinforces the stability of nature as a sign of God's faithfulness so frequently expressed in the Old Testament (Jer. 31:35–36; 33:25–26), while leaving open the possibility of miracles.

One of the medieval philosophers, Jean Buridan, was particularly interested in the nature of motion. This is the most fundamental problem of physics, and so if science is to begin it must begin here. In full consistency with his belief in creation, he wrote that "God, when He created the world, moved each of the celestial orbs as he pleased, and in moving them He impressed upon them impetuses which moved them without Him having to move them any more except by the method of general influence whereby He concurs as co-agent in all things which take place."

This reinterprets the dictum of Aristotle, who required the continuing action of an mover throughout the motion. The mover is now located within the body, and what Buridan called impetus was later refined into the concept of momentum, and his insight became Newton's first law of motion. Buridan's works were widely published and his ideas became known throughout Europe, to Leonardo da Vinci, and to the scientists of Renaissance times.

The Christian belief in the creation of the world by God also undermined Aristotle's sharp distinction between celestial and terrestrial matter. Since they are both created, why should they be different? Indeed, Buridan illustrated his concept of impetus with reference to the long jump, thus implicitly presupposing that celestial and terrestrial motions are similar. This made it possible for Newton to see that the same force that pulls an apple to the ground also keeps the moon in its orbit.

### *Belief in the Order of Nature*

A vital component in the rise of science is the belief in the order of the world, that is, the idea that every event is the precise result of preceding events. This implies that whatever measurements we make should correspond exactly, that is, within the uncertainties of measurement, with our theories. A corollary to this is that if we want to test out theories, we should make the most accurate measure-

ments we can. This insistence on precision is essential for the progress of science. An illustration of this is the work of Kepler on the orbit of the planet Mars. Some very accurate measurements had been made of its position by Tycho Brahe, probably the most accurate that could be made before the invention of the telescope. Kepler resolved to find the orbit. He believed, following Aristotle, that the orbit was circular, as befits incorruptible celestial matter. He found that indeed it is very nearly a circle, but however hard he worked, he could not make it fit Tycho's measurements. He could find a circular orbit that agreed with the measurements to about ten minutes of arc, but not to two, which was the accuracy of the measurements. Many people would have said that this was good enough, and gone on to do something else. But it was not good enough for Kepler, who believed that the fit must be exact, within the uncertainties of the measurements. So he toiled on and on for years, until he finally realized that he could never get the circle to fit. Then he tried an ellipse, and now the orbit could be fitted. This was a breakthrough that made possible Newton's work on the planetary orbits, when he showed from his theory of celestial dynamics that they must indeed be ellipses.

This vital stage in the development of science was made possible by the strong belief in the order of nature. This is what led Whitehead to say, in his Lowell lectures in 1925 on Science and the Modern World that "the Middle Ages formed one long training of the intellect of Western Europe in the sense of order." This by itself is not enough, and he went on: "I do not think that I have even yet brought out the greatest contribution of medievalism to the formation of the scientific movement. I mean the inexpugnable belief that every detailed occurrence can be correlated with its antecedents in a perfectly definite manner, exemplifying general principles. Without this belief the incredible labours of scientists would be without hope. It is this instinctive conviction, vividly poised before the imagination, which is the motive power of research: that there is a secret,

a secret which can be unveiled." He went on to ask how was this conviction so vividly implanted on the European mind, and concluded: "My explanation is that the faith in the possibility of science, generated antecedently to the development of modern scientific theory, is an unconscious derivative from medieval theology." One might indeed query whether unconscious is the right word, for many of the medievals explicitly saw their work as showing forth the works of the Creator.

*Science in Eastern Christendom*

This explanation of the rise of science in Western Europe during the High Middle Ages as due to the beliefs concerning the material world inherent in Christian theology raises the question why it happened in Western Europe and not in Eastern Europe where Christianity also flourishes. One might indeed have expected science to arise first in the east, because it was the heir to the wisdom of ancient Greece, preserved and to some extent developed by Arab scholars. Thus from the eighth to the fourteenth centuries mathematics, astronomy, optics, physics, and medicine were far more developed in Islamic countries than in Western Europe. In one vital area, for example, Arabic astronomers had so improved the Ptolemaic system that it was mathematically equivalent to the Copernican system, although it was still geocentric. And yet the lead was lost in one area after another as the West surged ahead and Arabic science decayed. This learning came to the West not via Eastern Christendom, but mainly through translations from the Arabic made in Spain. The Byzantine scientific tradition lacked originality, being content with the achievements of the Greeks and the Romans. They were thus unable to develop technology and to apply their theoretical knowledge for practical purposes.

Could the explanation of the difference between the vitality of science in the West and its virtual absence in the East be due to a dif-

ference between Eastern and Western theologies, or are there other explanations, perhaps in terms of sociological factors, which themselves may or may not have their origin in theology?

The theological beliefs of Eastern and Western Christendom are essentially the same, but there are important differences at the conceptual and practical levels. These differences are difficult to describe, because there are many counterexamples to any general statement that can be made. Thus both attach high value to reason and to prayer, but the emphasis is different. In the West, scholarly work is itself considered to be a form of prayer. Orders of friars, such as the Dominicans, were founded to preach, and to teach in schools and in universities, and their times of prayer are regulated to allow time for study. Dominicans such as Thomas Aquinas taught in the universities and used reason to find out what they could about God, thus developing Scholastic theology. In the monasteries of the East, the monks spend long hours in contemplative prayer and thus attain a knowledge of God, but as a result inevitably they have less time for study and for writing.

Of great importance for the origin of science is the concept of time. Before the advent of science our activities followed biological time, governed by the natural processes of night and day, the phases of the moon, and the progression of the seasons. In contrast, scientific time is a regular sequence, and to each instant there corresponds a number, measurable to high accuracy. Monasteries need to have a way of marking the time to regulate the hours of prayer and work and initially they followed biological time, supplemented by sand and water clocks. In the Western monasteries, clocks of high sophistication were developed as early as the twelfth century, whereas clocks, imported from the West, were not used on Mount Athos until the eighteenth century. Even now, the East has a more relaxed sense of time.

The use of biological time is associated with primitive technology, whereas more developed technology comes with scientific

time. Thus the larger Western monasteries made many technological advances for domestic and industrial purposes, such as water mills and saws. This is of crucial importance for the development of science.

There are also several sociological reasons why science arose in the West and not in the East. It is essential for creative intellectual work that there are places where it can be carried on without external interference, so that the people there are free to think what they like and to follow wherever their reason leads them. Such opportunities are provided by universities, and many were founded in the West from the twelfth century onwards. The crucial steps that led to the birth of modern science took place in the University of Paris.

In the East, there was a spectacular intellectual and artistic revival in the ninth century after the end of the iconoclastic controversy, and the University of Constantinople attracted many distinguished scholars. There was, however, little interest in science or technology.

Byzantine society was rigidly authoritarian, with Church and State closely linked. The Emperor was considered the vicegerent of God, and as ruler of both Church and State his word was law. There was a highly centralized state organization with a well-developed civil service, so that practically all activities were controlled by the Emperor. Trade and commerce were rigidly controlled, not to serve the interests of the merchants but to subordinate economic life to the interests of the State. There were indeed schools, but they did not encourage independent discussion, and the static conception of life was not conducive to the development of science. In the West, on the other hand, the universities were centers of intellectual discussions, where novel views were expounded and discussed.

People speak and discuss freely when they are personally secure, when they know that they may say what they like without danger of any kind. This security can be provided by belonging to an organization, such as a university, which encourages free discussions, or by

a society that respects the right of private property. In the West this is legally established, whereas in the East, property was held subject to the will of the ruler, and may at any time be revoked. If one lives in perpetual fear that the ruler will suddenly take away one's house, one is hardly likely to indulge in any activity that may incur the wrath of the ruler.

In the twelfth century the Crusaders caused consternation in Byzantium as they passed through on their way to the Holy Land, exacerbating the age-old tensions between East and West. These came to a head with the sack of Constantinople in 1204. Byzantium survived another two hundred years, but was fatally weakened and finally fell to the Turks in 1453.

Such sociological factors are sufficient to explain why science did not arise in Eastern Christendom, and it seems that these are more important than any theological differences.

An instructive example of the effect of sociological factors on intellectual activity is provided by the contrast between the English, French, and Spanish colonies in North and Central America on the one hand, and the Dutch colony in South Africa on the other. In America, there was from the first a thriving intellectual activity, with printing presses and newspapers, and great colleges and universities were founded within a few decades of the arrival of the colonists. Mexico was conquered in 1521, and by 1553 had a university. In North America, the colonists arrived in 1619, and Harvard was founded in 1636. In South Africa, on the other hand, everything was controlled by the Dutch East India Company, and profit was the only motive. There were no printing presses, newspapers, colleges, or universities. The Church was also partly to blame for this situation, because they insisted that their ministers be trained in Holland, and were not willing to establish colleges in South Africa.

## *Conclusion*

This brief survey shows that there are many factors of importance for the rise of science: material, sociological, and theological. The material conditions are found in many civilizations, and on their own are not decisive. A very special set of beliefs about the material world is necessary before science can begin, and these beliefs are provided by Christian theology. For science to develop, society must encourage the freedom of thought, and this partly depends on sociological factors, which are themselves often determined by theological beliefs. In all these ways, Christian theology has proved decisive for the birth and development of modern science.

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