INTRODUCTION

The “natural sciences” include physics, astronomy, geology, chemistry, and biology, and are usually referred to as such in contradistinction to the “human sciences,” such as anthropology, sociology, and linguistics. Of course, there is some overlap. Those disciplines which study human beings as biological organisms belong to both the natural and the human sciences.

In such a guide as this it would be impossible to give equal attention to all branches of natural science; I have therefore chosen to emphasize physics and, to a lesser extent, astronomy. There are several reasons for this choice. First, breakthroughs in these fields produced the Scientific Revolution and inaugurated the era of modern science. Second, physics can be regarded as the most fundamental branch of natural science, since the laws of physics govern the processes studied in all the other branches. Natural scientists tend to look at things from a “bottom up” perspective, in which the behavior of complex systems is accounted for in terms of the interactions of their constituents, and the branch of science that studies the most basic constituents of matter and their interactions is physics. Third, it
can be said that developments in physics and astronomy have had the most profound impact on philosophical thought—along with Darwin’s theory of evolution. Finally, there is the fact that I am myself a physicist.

Science was done in each of the great ancient civilizations of Asia, Africa, and the Americas. However, the story of science, as usually told, traces a path from the ancient Greeks and their precursors in Babylon and Egypt, through the Islamic world, and into Europe. There is good reason for this. All of modern science stems from the Scientific Revolution, which erupted in Europe in the 1600s and had its roots in the achievements of the ancient Greeks. The scientific developments that took place in other parts of the world in ancient times, though quite impressive in their own right, made little or no contribution to the Western Scientific Revolution and thus had hardly any lasting impact. (There are exceptions; for example, the concept of the number zero was first developed in India; it made its way into Europe through the Arabs.) From the sixteenth century through the nineteenth, advances in science came almost exclusively from within Europe’s borders. It was not until the twentieth century that science became a truly global enterprise.

THE BIRTH OF SCIENCE

Natural science in the West was born in Greece approximately five centuries before the birth of Christ. It was
conceived by the coming together of two great ideas. The first was that reason could be systematically employed to enlarge our understanding of reality. In this regard, one might say that the Greeks invented “theory.” For instance, while literature is as old as writing, and politics as old as man, political theory and literary theory began with the Greeks. So too did the study of logic and the axiomatic development of mathematics. One of the earliest Greek philosophers, Heraclitus (540–480 B.C.), taught that the world was in constant flux, but that underlying all change is Reason, or *Logos*. 

The second great idea was that events in the physical world can be given natural—as opposed to supernatural, or exclusively divine—explanations. The pioneer of this approach was Thales of Miletus (625–546 B.C.), who is said to have explained earthquakes by positing that the earth floated on water. He is most famous for speculating that water is the fundamental principle from which all things come. Thales was thus perhaps the first thinker to seek for the basic elements (or in his case, element) out of which everything is made. Others proposed different elements, and eventually the list grew to four: fire, water, earth, and air.

The search for the truly fundamental or “elementary” constituents of the world has continued to this day. In 1869, Mendeleev published his periodic table of chemical elements (which at that point numbered sixty-three). Later, the atoms identified by chemists were found to be composed of subatomic particles, which are now studied in the
branch of science known as elementary particle physics. Today it is suspected that these particles are not truly elementary but are themselves manifestations of “superstrings.” If this present speculation proves to be correct, it will vindicate Thales’ intuition that there is but a single truly fundamental “stuff” of nature. In fact, as we shall see, this dream of theoretical unification and simplification has been progressively realized with each of the great advances of modern science.

The idea of “atoms” was the most remarkable and pre-scient of all the ancient Greek scientific ideas. It was proposed first by Leucippus (fifth century B.C.) and Democritus of Abdera (c. 460–370 B.C.). The Nobel laureate Richard Feynman, in his great Lectures on Physics, wrote,

If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence were to be passed on to the next generation of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis . . . that all things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another.¹

Of course, the rudimentary version of atomism proposed by Leucippus and Democritus was not a scientific theory in our modern sense. It could not be tested, and it led to no research program, but rather remained, as did most of Greek natural science, at the level of philosophical speculation.
Archimedes (c. 287–212 B.C.), one of the great figures of mathematical history, was born in Syracuse, Sicily. He discovered ways of computing the areas and volumes of curved figures, methods that were further developed by Torricelli, Cavalieri, Newton, and Leibniz in the seventeenth century in order to create the field of integral calculus. Unlike most Greek mathematicians of antiquity, Archimedes was deeply interested in physical problems. He was the first to understand the concept of “center of gravity.” He also founded the field of hydrostatics, discovering that a floating body will displace its own weight of fluid, while a submerged body will displace its own volume. He used the latter principle to solve a problem given to him by King Hiero of Syracuse, namely, to determine (without melting it down) whether a certain crown was made from pure or adulterated gold. Hitting upon the solution while in the public baths, he ran naked through the streets shouting “Eureka!” (“I have found it!”), the eternal cry of the scientific discoverer.

Archimedes was also the discoverer of the principle of the lever, boasting, “Give me a place to stand and I will move the earth.” Legend has it that he helped defend Syracuse from a Roman siege during the Second Punic War by inventing fantastic and ingenious weapons, such as the “claw of Archimedes,” and huge focusing mirrors to ignite ships. According to Plutarch, “[Archimedes] being perpetually charmed by his familiar siren, that is, by his geometry, neglected to eat and drink and took no care of his person; . . . [he] was often carried by force to the baths, and when there would trace geometrical figures in the ashes of the fire, and with his fingers draw lines upon his body when it was anointed with oil, being in a state of great ecstasy and divinely possessed by his science.” During the siege of Syracuse, in spite of standing orders from the Roman general that the great geometer not be harmed, Archimedes was struck down by a Roman soldier while drawing geometrical diagrams in the sand. His last words were, “Don’t disturb my circles.”
The beginning stage of any branch of science involves simple observation and classification. Not surprisingly, much of Greek natural science consisted of this kind of activity. At times it was more ambitious and sought for causes and principles, but these principles were for the most part philosophical. In other words, they were not formulated into scientific laws in the modern sense. One thinks of Aristotle’s principle that “nothing moves unless it is moved by another.” This was meant as a general statement about cause and effect. It did not allow one to predict anything, let alone to make calculations.

It is interesting that the Greeks, for all their tremendous achievements in mathematics, did not go far in applying mathematics to their study of the physical world—astronomy being the major exception. This should not surprise us. It is perhaps obvious that the world is an orderly place, as opposed to being mere chaos; but the fact that its orderliness is mathematical is very far from being obvious, at least if one looks at things and events on the earth, where there is a great deal of irregularity and haphazardness. The first person to conceive the idea that mathematics is fundamental to understanding physical reality—rather than pertaining only to some ideal realm—was Pythagoras (c. 569–c. 475 B.C.). This insight was perhaps suggested to him by his research in music, where he discovered that harmonious tones are produced by strings whose lengths are in simple arithmetical ratios to each other. In any event, Pythagoras and his followers arrived at the idea that reality
at its deepest level is mathematical. Indeed, Aristotle attributed to the Pythagoreans the idea that “things are numbers.” This assertion may seem extreme, and doubtless did to Aristotle, but to the modern physicist it appears both profound and prophetic.

It is in the motions of the heavenly bodies that the mathematical orderliness of the universe is most apparent. This has to do with a number of circumstances. First, interplanetary space is nearly a vacuum, which means that the movements of the solar system’s various bodies are unimpeded by friction. Second, the mutual gravitation of the planets is small compared to their attraction to the sun, a fact that greatly simplifies their motion. In other words, in the solar system nature has provided us with a dynamical system that is relatively simple to analyze. This was vital for the emergence of science. In empirical science it is important to be able to isolate specific causes and effects so that they are not obscured or disrupted by extraneous and irrelevant factors. This normally has to be done by conducting “controlled” experiments (experiments, for instance, that allow one to compare two systems that differ in only one respect). Usually, it is only in this way that one gets a chance to observe interesting and significant patterns in the data. But it did not occur to the ancient Greeks to perform controlled experiments—or, for the most part, experiments of any kind. It is therefore very fortunate that they had the solar system to observe.

The first application of geometry to astronomy seems to have been inspired by Pythagorean ideals. Pythagoras
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himself suggested that the earth is a perfect sphere. Later, Eudoxus (c. 408–c. 355 B.C.) proposed a model in which the apparently complex movements of the heavenly bodies resulted from their motion in perfectly circular paths. These Pythagorean principles—that theories should be mathematically beautiful and that they should explain complex effects in terms of simple causes—have been tremendously fruitful in the history of science. But they are not sufficient. The mathematical approach of these earlier astronomers lacked a key ingredient, namely the making of precise measurements and the basing of one’s theories upon those measurements. In this respect Hipparchus (c. 190–c. 120 B.C.) far exceeded his predecessors and transformed astronomy into a quantitative and predictive science. He made remarkably accurate determinations of such quantities as the distance of the moon from the earth and the rate at which the earth’s axis precesses (the so-called precession of the equinox, a phenomenon that he discovered). After Hipparchus, the development of ancient Greek astronomy reached its culmination in the work of Ptolemy (c. 85–c. 165), whose intricate geocentric model of the solar system was to be generally accepted for the next fifteen centuries.

The Greeks’ attraction to mathematics was a double-edged sword. On the one hand, it had incalculable benefits for science. The Greeks’ most enduring scientific legacy lay in their mathematics and mathematical astronomy. On the other hand, this attraction to mathematics reflected a tendency (seen very markedly in Plato) to disdain the world
of phenomena for a more exclusive focus on the realm of the ideal.

We find quite the opposite tendency in Aristotle. Aristotle was very much interested in phenomena of every kind, and (in contrast to many of his later epigones) engaged in extensive empirical investigations, especially in biology. He was undoubtedly one of the greatest biologists of the ancient world. His legacy in physics, however, is more ambiguous—indeed, on the whole, perhaps negative. There are several reasons for his comparative failure as a physicist. First, there is the fact, already remarked on, 

**Hipparchus** (c. 190–120 B.C.) is considered the greatest observational astronomer of antiquity. Little is known of his life except that he was born in Nicaea, located in present-day Turkey, and spent most of his life on the island of Rhodes. What distinguished him from his predecessors was his application of precise measurements to geometrical models of astronomy. Not only did he make extensive measurements; he also made use of the voluminous astronomical records of the Babylonians, which dated back to the eighth century B.C. This long span of data allowed him to compute certain quantities with unprecedented accuracy.

Hipparchus created the first trigonometric tables, which greatly facilitated astronomical calculations, and developed or improved devices for astronomical observation. He also compiled the first star catalogue, which gave the positions of about one thousand stars. Though he worked on many problems, such as determining the distance to the moon, he is most famous for discovering the “precession of the equinox” and correctly attributing it to a wobbling of the earth’s axis of rotation. Newton later showed that this wobbling was caused by the gravitational torque exerted by the sun and moon on the earth’s equatorial bulge.
that terrestrial phenomena are hard to sort out. Among many other complications, they involve large frictional forces, which resulted in Aristotle being fundamentally misled about the relationship between force and motion. Second, Aristotle appreciated neither the true nature of mathematics nor its profound importance; his genius lay elsewhere. Third, Aristotle’s approach to the physical sciences was philosophical; in his thought there is no bright line between physical and metaphysical concepts. This would not have created so many problems for later thought—problems discussed in more detail below—had it not been for the very brilliance and depth of Aristotelian philosophy.

THE SECOND BIRTH OF SCIENCE

It is sometimes said, by those with an axe to grind against religion, that the rise of Christianity brought an end to the first great age of scientific progress. This claim is untenable. It is true that one can find statements in the writings of the church fathers that deprecate the study of nature, and that science was not high on the early Christians’ list of concerns. However, one finds the same range of attitudes toward science among the early Christians as among their pagan contemporaries. And the fact is that the glory days of ancient science were long gone by the time Christians became a significant demographic or intellectual force. The golden age of Greek mathematics ended
two hundred years before the birth of Christ. (For example, the great Greek mathematicians Archimedes, Eratosthenes, and Apollonius of Perga died, respectively, in 212 B.C., 194 B.C., and 190 B.C.) Only a few great figures in ancient Greek science date from the period after Christ, notably the astronomer Ptolemy, who died around A.D. 165, and the mathematician Diophantus, who died around A.D. 284. At that point, Christianity was still a small and persecuted sect.

As is well known, an impressive revival of mathematics and science began in the Islamic world in the ninth century. Under the Abbasid caliphate, which stretched from North Africa to Central Asia, scholars were able to draw upon the patrimony of the Babylonians and Indians as well as the Greeks. The Muslim contributions to science are memorialized in the many scientific terms of Arabic origin, such as *alcohol* and *alkali* in chemistry (a field of inquiry once called “alchemy”); *algebra*, *algorithm*, and *zero* in mathematics; and *almanac*, *azimuth*, *zenith*, and the names of the bright stars *Algol*, *Aldebaran*, *Betelgeuse*, *Rigel*, and *Vega* in astronomy. However, the brilliance of Muslim science began to fade after a few centuries. The Islamic theological establishment tended to be indifferent or hostile to speculative Greek thought, and therefore science did not achieve the kind of institutional status in the Muslim world that it later achieved in the universities of Europe.

The second birth of science really came in the Latin West. In the eleventh century, when Western Europe be-
gan to recover from the economic and cultural collapse caused by the barbarian invasions, its scholars became aware again, largely through contact with the Arab world, of the ancient Greeks’ great achievements in science. This awareness engendered an insatiable curiosity about and demand for the works of ancient Greek scholars, which led in turn to a frenzy of translations of these works into Latin, either from Arabic sources obtained in Spain or directly from Greek versions obtained from the Byzantines. Universities were invented in medieval Europe, and they were founded in part as places where this newly recovered knowledge could be studied. The intense interest in Greek science—or, as it was called at that time, “natural philosophy”—was shared by clergy and laity alike. Indeed, in medieval universities the study of natural philosophy was a prerequisite for the study of theology. (This would be somewhat analogous to physics being a required course in today’s seminaries.)

For a long time, it was standard for modern scholars to dismiss medieval science as lacking in creativity or true scientific spirit, and as being quite irrelevant to later scientific progress. However, scholars such as Pierre Duhem and A. C. Crombie successfully challenged that consensus. They demonstrated that medieval science was far more vital than had been supposed, and that the picture of monkish scholars slavishly following Aristotle had been overdrawn. The “natural philosophers” of the Middle Ages were quite aware of some of the inadequacies in Aristotle’s ideas and adopted a cautiously critical approach to him, though their inter-
testing critiques were not based on experiments but on logical reasoning—and to some extent on what we would today call “thought experiments.” In addition, the medievals took tentative steps toward developing a science of motion. The crucial concept of uniform acceleration (or in their quaint terminology, “uniformly difform” motion) became understood for the first time; the notion of “impetus” (an anticipation of the concept of “momentum”) was developed; graphs were invented to facilitate reasoning about mathematical functions and motion; and mathematical laws of motion were first proposed. Some historians, such as Duhem, Crombie, and more recently Stanley Jaki, have even claimed that these ideas directly influenced the thinking of Galileo and other founders of the Scientific Revolution (though the extent of this influence is disputed, and the issue is far from settled).

Be that as it may, there is one way in which the revival of science in medieval Europe certainly did lay the groundwork for the Scientific Revolution to come. It “institutionalized” science, as Edward Grant, the noted historian of science, has put it. In the ancient and Arab worlds, science like art had depended upon the patronage of wealthy or powerful individuals who happened to have a personal interest in it. It was therefore a hit-or-miss affair, subject to the vicissitudes of politics and economic fortunes. By contrast, in the medieval universities there was created for the first time a stable community of scholars that studied scientific questions continuously from generation to genera-
tion. That is, a scientific community came into being. By the end of the Middle Ages there were nearly one hundred universities in Europe, and their graduates numbered in the tens of thousands. This created a significant literate public that was interested in science, was willing to pay to be taught or obtain books about it, and from whose ranks scientific talent could emerge.

Without the scientific community and the scientific public created by the medieval universities, the Scientific Revolution would not have had fertile soil in which to germinate.

**SCIENCE, RELIGION, AND ARISTOTLE**

The foregoing discussion raises two very interesting and difficult questions: Why did the Scientific Revolution occur in Europe, and what was the role of religion in that revolution? One view, encountered so frequently that it has become a cliché, is that the Christian religion was the enemy of science and tried to strangle it at its birth; this animus is alleged to have been clearly revealed in the Galileo affair. However, scholars no longer take this view seriously. The idea that the church establishment has been implacably hostile to science is a myth created to serve the purposes of antireligious and anticlerical propaganda.

In fact, the church has always esteemed scientific research—even at the time of the Galileo affair. We have seen that the medieval church was willing to embrace the
science of the ancient Greeks, even though it was naturalistic in character and pagan in origin, and that this science had an important place in the curricula of medieval universities, institutions that had been founded primarily under church auspices, received much church patronage and protection, and were staffed largely by clerics. Indeed, most of the scientists of the Middle Ages were clergymen, such as Nicholas Oresme (c. 1323–82), who was bishop of Lisieux and a mathematician and physicist of great ability. This tradition of clergy involvement in scientific research has continued to the present day. In fact, from the seventeenth through the twentieth century, a remarkable number of important scientific contributions have been made by Catholic priests.²

The favorable attitude of the church toward “natural philosophy” was largely the result of the efforts of St. Albert the Great, who helped introduce Greek science into the medieval universities, and his pupil St. Thomas Aquinas. Both men were convinced of the possibility and importance of harmonizing faith and reason and saw in the philosophy of Aristotle the conceptual tools needed to accomplish that. This gave a tremendous impetus to the study of natural philosophy and thereby helped prepare the way for the Scientific Revolution. However, the church’s embrace of Aristotle also had negative consequences, since it helped to cement in place a mistaken approach to the physical sciences.

The philosophical system of Aristotle, as transformed and Christianized by St. Thomas Aquinas, was a brilliant
Oresme, Nicholas (c. 1323–82) was born near Caen, Normandy, received his doctorate in theology from the University of Paris, became counselor and chaplain to the king of France, and was ultimately installed as the bishop of Lisieux. A polymathic genius, he made pioneering contributions in mathematics, physics, musicology, and psychology. He was an important figure in scholastic philosophy, and is considered by many to be the greatest economist of the Middle Ages. In mathematics, he was the first to discuss fractional and even irrational exponents, and his studies of infinite series proved that the harmonic series \((1 + 1/2 + 1/3 + 1/4 + \ldots)\) diverges. Oresme was also the first to use graphs to plot one quantity as a function of another, extending his discussion to three-dimensional graphs, thus anticipating by three centuries some of the key ideas of Cartesian analytic geometry. He used such graphical methods to give the first proof of the “Merton theorem,” which provides the distance traversed by a uniformly accelerated body. These studies probably contributed indirectly to Galileo’s discovery of the law of falling bodies.

In addition to all this, Oresme proved that phenomena could be accounted for satisfactorily by assuming that the earth rotates rather than the heavens. The analysis by which he refuted common physical objections to this was superior to those later articulated by Copernicus and Galileo, especially in its resolution of motion into vertical and horizontal components. He was the first to understand the distortion of the apparent positions of celestial objects near the horizon as resulting from the bending of light passing through air of varying density. And he argued for the existence of an infinite universe, contrary to the standard Aristotelian view. All in all, he must be accounted one of the great original thinkers in the history of mathematics and physics—and an important forerunner of the Scientific Revolution.
phy, and much else, including even truths of revealed religion (insofar as they could be grasped by human reason). This Aristotelian-Thomistic philosophy has great strengths and remains indeed very much a living tradition. However, for all the light Aristotle’s ideas shed upon metaphysical and moral issues, they contained much that was deeply mistaken and misleading when it came to physics and astronomy.

It is foolish to fault the medievals for adopting Aristotle’s physics, for there was nothing else around; it was the science that they inherited from the Greeks. And for a time it did play the useful function (as even wrong theories can) of providing a framework for theoretical discussion and analysis. It also provided an example of a naturalistic theory of physical phenomena, which is no small thing. Nevertheless, it had the effect of leading scientific thought into a cul-de-sac from which it took considerable effort to escape. To the extent that theology contributed to prolonging the dominance of Aristotelian natural philosophy, it played an unhelpful role.

The dominance of Aristotelianism helps to explain the church’s condemnation of Galileo and heliocentric astronomy in 1633. However, it was only one factor in a very complex affair. The other reasons for Galileo’s condemnation included professional rivalry, Galileo’s talent for making enemies, and, most important of all, the turbulence of the times. It was an era of great religious tension; Europe was being torn apart by the Thirty Years War, which had
begun as a Catholic-Protestant struggle. As part of its effort to defend itself against the Protestant challenge, the Catholic Church had enacted at the Council of Trent (1545–63) a set of rules for the interpretation of scripture

**Galileo, Galileo** (1564–1642) was born in Pisa and began studies at the University of Pisa in 1581. He secured a professorship there in 1589, but decided to move to the University of Padua two years later because of conflicts with Aristotelians. In 1609, having heard of the invention of the telescope, he devised his own and with it began studying the heavens. His discoveries of sunspots, the moons of Jupiter, mountains on the moon, and the phases of Venus undermined Aristotelian science, refuted the Ptolemaic system, and made him a celebrity. He aroused opposition by his advocacy of the heliocentric Copernican system, and in 1616 the Roman Inquisition issued an injunction forbidding him to defend Copernicanism “in any way.” At the same time, all books were prohibited that advocated Copernicanism as true rather than merely as a “hypothesis” (by which was meant a mathematical device for simplifying calculations). In 1623, Maffeo Cardinal Barberini, a friend and protector of Galileo, was elected pope. Unaware of the 1616 injunction, he did not object to Galileo defending Copernicanism as a “hypothesis.” Galileo proceeded to publish in 1630 his *Dialogue Concerning the Two Chief World Systems*, in which he not only defended Copernicanism as true, but seemed also to lampoon the pope’s philosophical opinions. The pope was outraged at this betrayal by someone he had protected; the forgotten 1616 injunction was discovered in the files; and in 1633 Galileo was forced to publicly renounce Copernicanism and sentenced to lifelong house arrest, which he served in his villa in Florence, where he was allowed to receive visitors and publish on other scientific subjects. In 1638 he published his *Dialogues Concerning Two New Sciences*, which set out his discoveries in physics, his greatest contributions to science.
that was intended to prevent radical theological innovations. Though reasonable in themselves, these rules ended up being misapplied to Galileo, who had unwisely allowed himself to be drawn into scriptural and theological debate by his enemies.

The condemnation of Galileo, though a fateful blunder, was not the result of hostility toward science on the part of church authorities, nor did it reflect an unyielding dogmatism in scientific matters. The words of Cardinal Bellarmine, head of the Roman Inquisition at the time of Galileo’s first encounter with it in 1616, are well worth remembering:

If it were demonstrated that [the sun was really motionless and the earth was in motion] we should have to proceed with caution in interpreting passages of Scripture that appear to teach the contrary, and rather admit that we do not understand them than declare something false which has been proven to be true.

Bellarmine went on to say that he had “grave doubts” that such a proof existed and that “in case of doubt” one must stay with the traditional interpretation of scripture. As a matter of fact, such a proof of heliocentrism did not exist in Galileo’s time, though there were strong indications in its favor for those with eyes to see them.

In any event, if we look at the eight-hundred-year record of the church’s involvement with science, it is hard to see the Galileo affair as anything but an aberration. Far from
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seeing religion as an obstacle to the emergence of modern science, some scholars have argued that Christian beliefs played a part in making the Scientific Revolution possible. A great deal can be said for this view. For example, an idea fundamental to all science is that there exists a natural order. That is, not only is the world orderly, but it is in fact a natural world. We have seen that this idea arose among the pagan Greek philosophers, but Judaism and Christianity also helped promote this way of thinking. Whereas in primitive pagan religion the world was imbued with supernatural and occult forces and populated by myriad deities—gods of war, gods of the ocean and of the earth, goddesses of sex and fertility, and so forth—Jews and Christians taught that there was only one God who was to be sought not within nature and its phenomena and forces, but outside of nature, a God who was indeed the author of nature. In this way, biblical religion desacralized and depersonalized the world. To borrow Max Weber’s term, it “disenchanted” the world.

For example, the book of Genesis, which is often seen as an instance of primitive mythmaking, was actually written in part, scholars tell us, as a polemic against pagan supernaturalism and superstition. When Genesis says that the sun and moon are merely “lamps” placed by God in the heavens to light the day and night, it is attacking the pagan religions that worshipped the sun and moon. When it says that man is made “in the image of God” and is to exercise “dominion” over the animals, Genesis is, among
other things, attacking the paganism in which men worshipped and bowed down to animals or to gods made in the image of animals.

Medieval Christians were so comfortable with a naturalistic view of the physical world that it was commonplace as early as the twelfth century, according to Edward Grant, for philosophers and theologians to refer to the universe as a *machina*, a “machine.” (Of course, both Judaism and Christianity teach the possibility of miracles. But miracles—from the Latin *mirari*, “to wonder at”—are such precisely because they are rare occurrences that contravene what the medieval philosophers called the “course of nature.” They derive their whole significance from the fact that there is a natural order that only God, as author of nature, can override.)

A second idea that Judaism and Christianity likely helped to foster is that the universe is not merely orderly but *lawful*. A Christian writer of the second century, Minucius Felix, wrote:

> If upon entering some home you saw that everything there was well-tended, neat, and decorative, you would believe that some master was in charge of it, and that he was himself much superior to those good things. So too in the home of this world, when you see providence, order, and law in the heavens and on earth, believe that there is a Lord and Author of the universe, more beautiful than the stars themselves and the various parts of the whole world.