

CHRISTIAN HISTORY

Issue 76: The Christian Face of the Scientific Revolution

The Christian Face of the Scientific Revolution: Did You Know?

Interesting and unusual facts about Christians in the scientific revolution.

editors

Astronomer by Night, Canon by Day

When Nicolaus Copernicus wasn't redrawing the celestial map, he held down a day job as a Catholic canon (ecclesiastical administrator). As the Reformation grew rapidly and extended its influence in Poland, Copernicus and his respected friend Tiedemann Giese, later bishop of Varmia, remained open to some of the new ideas.

Copernicus did not leave a written record of his views, but he authorized Giese to quote him in a book supportive of a mediating position he hoped would avoid disruption in the church. He also consorted openly with at least two Lutherans—his first and only disciple, Georg Joachim Rheticus, and the well-known Lutheran clergyman, Andreas Osiander (also recognized for competence in mathematics and astronomy).

This might have sunk the career of most Catholic functionaries, but friends in high places kept Copernicus's job for him.

When, decades later, Galileo was attacked for promoting Copernicus's heliocentric cosmology, he defended himself by reminding his opponents that the Polish astronomer had been "not only a Catholic, but a priest and a canon." Galileo got two out of three right—although Copernicus did serve his church faithfully for 40 years, like many other canons of his day he never pursued ordination.

"Bodily Up" to Modern Science

We often associate the birth of modern science with Galileo Galilei, who sought to prove Copernicus's cosmology empirically with his telescopes. However, the scientific revolution did not begin at the outer frontier of space, but rather at the inner frontier of the human body. The 1543 publication of *De Humani Corporis Fabrica* by the Flemish scientist and churchman Andreas Vesalius not only created anatomical science as we know it, but was arguably the coming-out party of modern observational science and research.

More, it epitomized Renaissance advances in engraving and printing: The woodcut for the title page of *De Fabrica*, with its precise lines, fine shadings, and skillful rendering of perspective, is recognized as one of the finest engravings of the sixteenth century. And the plates within the book were likely created in the workshop of the great Venetian painter Titian (Tiziano Vecellio, ca. 1485-1576), after sketches by Vesalius.

Dads of Science

Many of the innovators during the scientific revolution seem to have been—though such things are notoriously difficult to determine—more than nominal Christians. Consider these "fathers" featured in this issue:

Andreas Vesalius (1514-1564) "Father of modern anatomy"

Galileo Galilei (1564-1642) "Father of modern astronomy"

William Harvey (1578-1630) "Father of modern medicine"

Robert Boyle (1627-1691) "Father of modern chemistry"

Antony van Leeuwenhoek (1632-1723) "Father of microbiology"

Isaac Newton (1642-1727) "Father of modern mechanistic physics" (and, with Leibnitz, of calculus).

Music of the Spheres

In 1616, astronomer Johannes Kepler pursued a longstanding interest in music in an unusual direction. He developed a system of musical notation to represent the variations in the speed of each planet when nearest to and furthest from the sun. The harmonies produced by the planets' notes, he felt, proclaimed the glory of God. He used just two notes to represent the relatively small change in the earth's speed, lamenting, "The Earth sings Mi-Fa-Mi, so we can gather even from this that Misery and Famine reign on our habitat." He published this research as ***Harmonies of the World*** (1618).

Seemingly a quirky diversion, these musical investigations led Kepler to the discovery of the principles of planetary motion, which, 40 years later, would spur Isaac Newton to develop his theory of universal gravitation.

Kepler was not the only early modern scientist to make his mark in music. Famed physicist and chemist Robert Boyle wrote romances (fictional works) on moral and religious subjects. One of these, ***The Martyrdom of Theodora, And of Didymus***, became the basis for Handel's opera ***Theodora***. Isaac Watts based a four-line hymn upon one section of Boyle's ***Occasional Reflections Upon Several Subjects***, a work highly popular among the Puritans, which remained in print for two centuries. The Watts hymn was later set to music by the great colonial American composer William Billings as part of his anthem, ***Creation***.

Fighting Meltdowns and Clippers

Copernicus and Newton shared more than an interest in the heavens. Both labored against abuses of their respective nations' currencies.

Copernicus became deeply concerned at corruptions in the use of the local currency in his town of Olsztyn. The percentage of silver in the coins was being reduced. Unaware of that fact, the peasants continued to pay for their purchases with the older, more valuable coins, which were then melted down. Copernicus wrote an "Essay on the Coinage of Money" in 1517, which he circulated among trusted friends. In 1528, he presented to the legislature recommendations for the minting of new coins, which sank under special-interest lobbying.

Newton was even more famously involved in protecting his national currency. In his day, the economy of England suffered due to the immoral practice of clipping—that is, cutting slivers off the edges of the coins to be melted down and sold, leaving the central part of the coin sufficiently intact to serve, albeit suspiciously, as currency. Newton was appointed warden (1696-1699) and master (1699-1727) of the Royal Mint, and he set out to save England's economy with his usual hyperfocus. He worked 16 hours a day at the stupendous task of overhauling production at the mint and recalling and re-minting all the

realm's coins. His zeal carried him into the back alleys of London, where he roamed in disguise, befriending the unsuspecting counterfeiters and coin clippers, drawing out their confessions, and then prosecuting them and sending them to the gallows for treason.

The *Real* Christian Face of the Scientific Revolution?

Our cover image is *The Astronomer*, painted by the Dutch master Vermeer Van Delft (1632-1675), ca. 1668. After Raymond Whitlock, our art director, chose the image, he was delighted to discover a probable connection with one of the scientists featured in this issue.

Both this painting and its companion, *The Geographer*, show a sophisticated awareness of scientific books and instruments. Thus art historians believe Vermeer conferred with a scientist—probably the young man who modeled for both paintings—as he painted.

The most likely candidate is Dutch microscopist Antony van Leeuwenhoek (1632-1723; see pp. 42-43). Leeuwenhoek was born in Delft the same year as Vermeer. They shared a fascination with science and optics, and their families were both in the textile trade. In 1668, Leeuwenhoek would have been 36 years old—plausibly the age of the sitter. The physical features of the sitter resemble those of a portrait of Leeuwenhoek made in 1686 by the Delft artist Jan Verkolje (1650-1693). In 1676, the scientist was named trustee for Vermeer's estate.

Two details further suggest a Christian connection. The first is the painting on the wall, depicting the finding of Moses. This suggests a spiritual interpretation of a second detail, the stance of the astronomer, who, in reaching for his celestial globe, may be thought to search for spiritual guidance.

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The Christian Face of the Scientific Revolution: From the Editor - The Specter of Enmity

Chris Armstrong

Before I started working on this issue, I had always harbored (though fancying I knew better) a vague, unsettling notion that the things of science and the things of God are somehow incompatible. Attached to this was an equally disturbing sense that, throughout its history, the church had seen science as a potential threat to the faith.

This shadowy sense of a historical tension between faith and science is a pretty disruptive poltergeist in the mental house of any modern Christian who suffers with it. For, after all, we live this science. Even the confirmed Luddites among us find our lives entangled, improved, and burdened a hundred ways each day by modern science. And we live, or try to live, this faith. That is, we know we have our being in God and should have our minds conformed to Christ while at our computers, in our cars, at the doctor's office, and everywhere else science meets us.

So if there's some kind of inherent opposition between faith and science, this is a problem.

*Is there, then? Or at least, **has there been?***

Historian of science David Lindberg lays out a panoramic answer to this question in this issue's Link Interview (p. 44). Lindberg traces the long history of the interaction between Christianity and science back to the earliest days of the faith, and what he finds there is eye-opening.

Philosopher Peter Harrison adds a dimension to this long view as he identifies, in his "God of Math and Order" (p. 18), three changes in Christian theology that contributed to the progress of scientific revolution.

A more impressionistic answer, with some of the mysterious power of impressionist paintings, develops out of the rich colors and fine details of this issue's biographical articles. Here emerges, life by fascinating life, a group portrait of individuals gifted with a genius for studying the natural world.

These men were quirky, sometimes unorthodox in their theology, often struggling with aspects of their faith. Yet they were convinced, to a man, that when they peered through their lenses, worked out their equations, or conducted their experiments, they were gaining a privileged insight into God's glory, in all of its macroscopic and microscopic detail.

This approach—the design of this issue as a gallery of mini-biographies chosen to illustrate a topic—is a new one for us. But I think it works. It leads us out of the fog that hangs around this subject and helps us discover what was always there, hidden behind: the tremendous power and attractiveness of science practiced as a Christian vocation.

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Galileo and the Powers Above

The convoluted tale of a faithful Catholic caught in a web of theological inflexibility, papal power, and his own political naivete.

Virginia Stem Owens

Say the name Galileo, and most people picture the astronomer standing before scowling Inquisition judges, forced to recant his claim that the earth revolves about the sun.

To secular scholars, Galileo Galilei (1564-1642) was a martyr to religious bigotry, demonstrating how pious superstition can shackle human knowledge. To Protestant historians, Galileo's fate is a sharp contrast to the freedom other Enlightenment luminaries, like Robert Boyle, Isaac Newton, and Johannes Kepler, enjoyed in Reformation regions.

But there's more to Galileo's story. Born in 1564 into a Europe passionate—and passionately divided—about its faith, the astronomer experimented, observed, and published his findings without ecclesiastical restraint for almost seventy years before his run-in with the papal authorities. He lived and died just as faithful to the Roman Church as Boyle was to the Anglican or Kepler to his Lutheran roots.

This stands in contrast to the network of thinkers and tinkerers, self-styled "the New Philosophers," who would help bring the scientific revolution to full flower. Many of those men paid little attention to the commitments of nationality or religion that divided their contemporaries. They considered themselves citizens of a borderless and nonsectarian commonwealth of science. Indeed, for some, their allegiance to the pursuit of verifiable truths about the natural world superseded all other commitments. The Dutch mathematician and physicist Christiaan Huygens, for example, declared, "The World is my Fatherland, Science is my Religion."

Despite Galileo's faithfulness to his church, he is most often portrayed today as a secular scientific hero who stood firm against religious bigotry. His loyalty to his faith is largely ignored. Internationally famous by middle age, he might easily have found more intellectual freedom in England or the Dutch states or even in the French court. Yet he remained in Italy and submitted to an Inquisition he considered ignorant and a pope who used him as a political pawn.

Astronomy's new star

Galileo's career launched in 1604, when he demonstrated that a new star, a supernova, was further away than the moon. This may strike the modern reader as fairly obvious, but the cosmological implications for the early seventeenth century were enormous. His study of the new star confirmed his growing belief in a Copernican—heliocentric—universe.

During this same year, Galileo began pursuing a fruitful patronage relationship by buttering up Cosimo II de Médici, who was slated to inherit his father's title as Grand Duke of Tuscany. The struggling academic dedicated one of his new inventions, a geometric and military compass, to Cosimo. Five more years would go by, however, before the old duke obliged his scion (and gave hope to the astronomer) by dying.

Meanwhile, Galileo supplemented his income by selling his newly invented compass to students, along with a handbook on how to use it. He also invented a primitive thermometer and a barometer. He wrote

voluminously, notably on the long-debated phenomenon of motion.

When Cosimo II married in 1608, Galileo produced, as a kind of wedding present for his future patron, a 56-ounce lodestone (magnet) capable of lifting over twice its weight in iron. The astronomer proposed the lodestone as a fitting emblem of Cosimo's own strength and powers of attraction.

The following year, two events occurred that would change Galileo's future. First, the old Duke of Tuscany died, leaving the way clear for his son to assume his position.

Second, Galileo heard of a Dutch invention, a "spyglass," which brought far distant objects near. Galileo set to work and, by the end of the year, produced his own version with much greater magnification.

Early in January 1610, Galileo made a number of discoveries, using the spyglass he continued to upgrade. He found mountains on the moon, saw that the Milky Way was actually composed of stars, and discovered four satellites around Jupiter, which he named the "Medician stars." He published these findings in a paper titled "The Starry Messenger," which, of course, he dedicated to the new Grand Duke Cosimo II.

Ousting Aristotle

His discovery and publication brought him the long-dreamed-of appointment as Cosimo's court mathematician. But as Galileo's fame grew, so did powerful opposition to his work, as it began to shake the foundations of a worldview based on Aristotle's assumptions about the cosmos.

The common understanding was that the universe was a set of nested concentric spheres, with our own planet at the center. Our moon was recognized as a satellite undergoing constant change, but the objects in the spheres beyond were immutable—an aspect of their perfection, according to Aristotle.

But Galileo, with his fascination for mathematics, insisted that the same measurements that worked on earth applied also to celestial spheres. He had already proved by verifiable experiment that Aristotle was wrong about falling objects. Now he further embarrassed Aristotelians by intervening in the effort to cast a new bell for Florence's city tower.

The city fathers of Florence, impressed with Galileo's steadily increasing fame, commissioned him to find a way to cast a new bell for the town. None of the local craftsmen could understand why the wooden mold for the bell's inner surface kept rising when molten metal was poured between it and the mold for the outer surface. Taking his cue from the ancient Greek Archimedes, Galileo explained that bodies must be heavier than the volume of liquid they displace or they will float to the surface. This refuted Aristotle, who claimed objects floated when they "pierced" the skin of a liquid and escaped from it. By increasing the pressure on the inner mold, the Florence bell-casters succeeded in their task.

So grateful were the city fathers for Galileo's solution to their problem that they held a state dinner at which the entertainment was a debate between Galileo and visiting clergy on the Aristotelian doctrine regarding liquids.

Among the guests was Cardinal Mafeo Barberini, who was impressed enough with Galileo that when he returned to Rome, he championed the astronomer's revolutionary ideas at the papal court.

Neither Barberini nor Galileo could foresee how their initially friendly relationship would change in the years to come.

War over the heavens

But now Galileo began to have serious detractors. Initially it was not the theologians who balked at Galileo's ideas. Mathematicians at the University of Pisa were so outraged that Galileo dared to challenge Aristotle that they refused to even look through his telescope at the stars.

Aristotle was the authority not just for physics, but for metaphysics as well. In the late thirteenth century, Thomas Aquinas had organized all current knowledge on a system based on the ancient philosopher's newly translated works. This had supplied Western philosophers with a powerful tool for making sense of the world. Whoever dismissed Aristotle's assumptions undermined the foundation of Aquinas's great cathedral of thought.

Even more serious was the charge that Galileo's teachings were inconsistent with those of the Bible. In 1613, the Dominican friar Tommaso Caccini preached a sermon in Florence attacking Galileo's views as heretical because they contradicted passages in Joshua where the sun stands still during the battle of Gibeon.

Galileo wrote to Benedetto Castelli, a former student, explaining his way of reconciling Scripture with scientific discoveries. Both the Bible and nature "proceed alike from the divine Word," he wrote. The Bible was given to reveal by divine revelation what human reason could not, unaided, understand—that is, matters of faith necessary for salvation. In Joshua, the Holy Ghost had shaped his language to take account of common concepts of the universe.

"But," concluded Galileo, "I do not feel obliged to believe that the same God who has endowed us with senses, reason and intellect has intended us to forego their use."

To support his position, Galileo reached back farther than Aquinas, to Augustine, who had himself addressed the question of cosmology, concluding that the shape, location, and motion of heaven as well as the stars were irrelevant to the matter of salvation, his chief concern. Quoting another of the Church Fathers, Galileo added that in the Bible, "the intention of the Holy Ghost is to teach us how one goes to heaven, not how heaven goes."

Somehow this letter fell into the hands of Caccini, who was ill-prepared to debate astronomy and whose grasp of exegesis was not much better. In his sermon denouncing Copernicanism, he used as the clincher Acts 1:11: "Ye men of Galilee, why stand ye gazing up into heaven?" A mangled version of Galileo's letter was sent to the Inquisition in Rome.

Hearing of this, Galileo sent his original version. (He later polished his letter and published it as "Letter to the Grand Duchess Christina," who had been particularly troubled by these questions.) But he was still not much alarmed. He knew he had a powerful friend in Bellarmine at the Vatican. He also knew that many of the best minds in Italy, including the Vatican's mathematicians, were convinced by the proofs of a heliocentric universe Galileo's observations provided. Caccini's Dominican superior was so embarrassed that he sent a letter of apology to Galileo.

But Caccini wasn't done. In 1615 he gave an unsolicited deposition to the Inquisition about Galileo's views, which demonstrated only his own ignorance of the subject. Nevertheless, the committee of theologians to whom the Inquisition referred the matter rendered their judgment, early the next year, that Copernican theory was "absurd in philosophy and formally heretical."

Thus Pope Paul V ordered Cardinal Bellarmine, Galileo's advocate in Rome, to warn the astronomer that henceforth he was not to hold or defend the Copernican theory. The following month, Copernicus's book ***On the Revolutions*** was put on the official Index of banned books. Before he left Rome, Galileo had an audience with the Pope, during which Paul V assured him that he had not been on trial in Rome nor had he been condemned—an official declaration Cardinal Bellarmine confirmed in a letter to Galileo the

following month.

Nevertheless, the warning got Galileo's attention. He returned to Florence and took up his investigation of more terrestrial problems in physics, like figuring out a way to determine longitudes at sea, and continued his earlier work on moving bodies.

The heavens themselves, however, now seemed to conspire against Galileo's church-imposed silence on celestial subjects. In 1618, three new comets appeared in the sky. Scholars and others, including the Grand Duke of Austria, wrote to Galileo requesting his opinion about the comets.

Meanwhile, a Jesuit mathematician at the Collegio Romano published a paper on the comets, one that Galileo found erroneous. Despite his ban, he could not bring himself to stay out of the fray. He worked with one of his students, composing a rebuttal, which was published under the student's name.

No one was fooled by this ruse. In fact, when the Jesuit mathematician published a reply—under his own pseudonym—he titled it "The Astronomical Balance, on which the Opinions of Galileo Galilei regarding Comets are weighed."

A friend in Rome?

This cat-and-mouse game does not appear to have damaged Galileo's relationship with his ecclesiastical friends in Rome. The following year, 1620, Cardinal Barberini sent him a poem he had composed in honor of Galileo. But as another year began, Pope Paul V died. His death was quickly followed by that of Cosimo II de' Medici, Galileo's patron.

Had the astronomer been a more astute politician, he might have recognized that his position was now more precarious. But Galileo seems rather to have imagined that the ban, if not officially lifted, had at least been forgotten in some dusty corner of the Vatican. He now composed a response to "The Astronomical Balance," titled "The Assayer." When the Roman censors gave their permission for its publication under his own name, Galileo breathed a sigh of relief.

Another death occurred the following month—this one seemingly providential. The deceased was Pope Gregory XV. Now Galileo's longtime friend, Cardinal Barberini, became Pope Urban VIII. The astronomer must have felt he was home free.

Galileo went so far as to change the dedication of "The Assayer" from his late patron to the new pope. Urban showed no sign of displeasure at this honor and indeed, when Galileo was in Rome the following year, granted him six audiences. During these, the new pope assured the astronomer that he was now free to write about the Copernican theory, provided he treated it as theory, not fact.

Returning to Florence full of confidence, Galileo set to work upon the manuscript that was to prove his undoing—*Dialogue Concerning the Two Chief World Systems*. The years spent in silence about the subject must have sorely chafed his pride, for he cast the work in the form of a satirical dialogue between two rivals, one supporting the Copernican view, the other—made to look a thick-headed fool—arguing for the old Ptolemaic version.

Completing the work took several years, during which various charges were levied against him with the Inquisition, all of which were dismissed.

Final verdict

In this interim, however, Urban VIII's focus shifted from such celestial investigations to a more earthly

problem—the Thirty Years War. Political alliances were unstable at best, and he could not afford to be seen as soft on Copernicanism if the papacy were to retain its shrinking power. Thus the *Dialogue* took two years to work its way through the Roman censors, and it was February of 1632 before it finally went to print.

Then, only a few months after publication, word arrived from Rome that Galileo was to stop distributing the new book immediately while the Inquisition further examined its contents.

In October, he was summoned to Rome to appear before the Inquisition, Urban VIII personally presiding. Galileo was now 67 years old and in bad health, but the pope threatened to drag him to Rome in chains if he did not come voluntarily.

For a month, Galileo, while being held under indefinite imprisonment and threat of torture, negotiated with canon lawyers, trying to come to a mutually satisfactory statement of his position. But Urban, his former friend, remained implacable. In the Church of Santa Maria sopra Minerva (where Caccini had become a Master and Bachelor), Galileo finally recanted his stated belief that the earth moves around the sun.

So debilitated was Galileo by his ordeal that it took months for him to make his way back to his villa on the outskirts of Florence. He was not permitted to leave it for the rest of his life, even to visit the doctor.

The aftermath

In the margins of his copy of the *Dialogue*, Galileo penned a silent rebuttal to the Inquisition: "Who can doubt that it will lead to the worst disorders when minds created free by God are compelled to submit slavishly to an outside will? When we are told to deny our senses and subject them to the whim of others?"

Galileo chafed under his ecclesiastical constraints. And indeed, except for the Scopes trial, no other single event so thoroughly cemented religion's reputation as the enemy of science. Yet he refused to emigrate or apostatize. Perhaps he was simply too old and sick to care. But he did continue to produce new scientific treatises.

Meanwhile, the rest of the world did not forget Galileo. An international succession of admirers, including the French ambassador, smuggled his work to foreign publishers. The young Milton, on his tour of the continent, visited him in his seclusion. The Dutch States General presented Galileo with a gold chain, a high tribute for the Catholic astronomer from that Reformation stronghold. Galileo declined it, however, a gesture for which Pope Urban VIII commended him.

None of these honors would have given Galileo as much satisfaction as the 1992 papal commission that formally acknowledged the church had erred in its treatment of the great Catholic astronomer.

Virginia Stem Owens is a writer living in Huntsville, Texas, who also serves on the editorial board of Books & Culture.

Galileo's Spiritual Director

Virginia Stem Owens

Since tradition proscribed marriage for university faculty, Galileo's lifelong union with Marina Gamba was not officially sanctioned. Marina bore Galileo two daughters and a son. His fatherly affection was as great as if they had been his legitimate offspring.

Knowing that his daughters, born out of wedlock, would therefore never be able to marry anyone but stable hands or peasants, Galileo got them accepted at ages 12 and 13 into a Franciscan community of Poor Clares near Florence. When his elder daughter, Virginia, made her final vows as a nun, she took the name Sister Celeste—a reference to her father's devotion to studying the heavens. The younger Livia took the name Sister Arcangela.

As the years went by, Sister Celeste assumed more and more of the responsibility for running the convent, which was desperately poor. Ironically, the plague that wracked Europe during these years never affected the convent, probably because rats found nothing to eat there.

One of the convent's few literate nuns, Sister Celeste must have been educated at home in her early years, quite possibly by her father. Over 100 of her letters to Galileo survive, evidence of how highly he valued her correspondence.

Through the years, she baked treats and did needlework for her father. And Galileo sent fresh fruits from his orchard and, before his house arrest, visited his daughters at the convent, which he could see from his villa above Florence.

Sister Celeste's help was not limited to cooking and sewing, however. She served as final copyist for her father's manuscripts. Before he left Florence for his disastrous last trip to Rome, he entrusted his financial affairs to his daughter, who had obviously inherited his mathematical aptitude. She also used her spiritual gifts to mediate conflicts between her father and brother.

Sister Celeste continued to write to Galileo during his ordeal with the Inquisition, concerned for his health, both physical and spiritual. Realizing that her letters might be seen by unfriendly eyes in Rome, she phrased her encouragement to her father tactfully.

When he expressed his frustration with ecclesiastical strictures, she advised patience and humility, neither of which were Galileo's strong suits. When the Inquisition ordered Galileo to say the penitential Psalms every week for the next three years, his daughter volunteered to take on the task on his behalf.

Unfortunately, Sister Celeste died of dysentery at thirtyfour, only four months after her father's return. A grieving Galileo wrote to a friend that his daughter had been "a woman of exquisite intellect and surpassing goodness."

—*Virginia Stem Owens*

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If there were a true demonstration

Owen Gingerich

In 1615, a Carmelite monk from Naples published a tract defending the Copernican system. In his reply, Rome's leading theologian, Cardinal Roberto Bellarmine, congratulated the monk for speaking hypothetically.

Yes, a heliocentric scheme "saved all the appearances" better than Ptolemy's epicycles—the small circular movements he had posited to account for the complicated wanderings of the planets against the background of the stars. But to affirm that "the sun is really fixed in the center of the heavens, and that the earth revolves very swiftly around the sun" was theologically suspect, as it seemed to contradict Scripture.

Bellarmino did admit, "if there were a true demonstration, then it would be necessary to be very careful in explaining Scriptures that seemed contrary," but he had certainly never seen any such demonstration—and did not think that one existed.

What kind of proof would have persuaded Bellarmine that the earth actually, not just hypothetically, revolved around the sun?

Copernicus had offered no physical proof, though his system did provide rational explanations of certain otherwise arbitrary aspects of planetary motions. When in 1610 Galileo with his newly improved telescope discovered the phases of Venus, he demonstrated that Venus had to go around the sun. But while his observation proved Ptolemy wrong, it did not necessarily prove Copernicus right.

As Bellarmine implied, just because assuming the sun is in the center of the universe with Venus going around it neatly explains the observed phases, this does not in fact demonstrate that the sun is actually in the center of the universe. Instead, the earth could be in the center of the universe, with, around it, the orbiting sun, which in turn could carry Venus and the other planets in orbit around it, just as the astronomer Tycho Brahe had proposed. For Bellarmine, the earth was still the glorious fixed pivot of all creation.

Galileo desperately wanted to find a proof that could persuade Bellarmine, but he died harassed by the Inquisition because he could not.

Today nearly every introductory astronomy text gives proofs of both the rotation of the earth on its axis (the so-called Foucault pendulum experiment) and its annual revolution around the sun (parallax, or the change in the apparent position of stars when the earth is at various points in its orbit). Would the Foucault pendulum and parallax have convinced Bellarmine in 1615? Probably not. He could easily have imagined that the daily whirling of the heavens around the earth in some way dragged the swing of the pendulum around with it. And the stars could each have a little epicyclet to provide their subtle and hard-to-detect annual motions. Then the literal meaning of Psalm 93 could be preserved: "The Lord God laid the foundation of the earth that it not be moved forever."

Why, then, are these proofs so convincing today, when they were unpersuasive in 1615? Today, Newton's system of natural laws is part of our heritage. It gives a coherent physical description of

motions both celestial and terrestrial, and physical explanations of many previously unexplained phenomena. The Foucault pendulum and parallax mesh perfectly in this system. So science marches on more by persuasion than by proof—and Galileo's efforts at persuasion, though thwarted in his lifetime, helped make it so.

—*Owen Gingerich*

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Upon Further Review...

Steven Gertz

Pope John Paul II reopened "the Galileo Affair" at a plenary session of the Pontifical Academy of Sciences in 1979. He urged theologians, scholars, and historians to study the Galileo case more deeply and to recognize "wrongs from whatever side they come," so as to "dispel the mistrust that still opposes a fruitful concord between science and faith."

He appointed several scholars to study the case, including then-bishop Paul Poupard. After more than a decade of meetings, Poupard presented the group's findings. He first defended the church's actions. As Galileo had not yet "proved" the heliocentric system, he wrote in the October 1992 issue of the Vatican newspaper *L'Osservatore Romano*, the church was right to give biblical passages describing the earth as immobile more weight than Galileo's theories. But Poupard also admitted that Galileo's judges made an "error of judgment" by failing to distinguish Christian faith from "age-old cosmology," and that they quite wrongly assumed Copernicus's revolution would undermine the church.

On October 31, 1992, Pope John Paul II pronounced the church's position in a speech to the Pontifical Academy. He admitted, albeit indirectly, that the church had erred on that day, 360 years ago, when it condemned the great Italian astronomer: "The majority of theologians did not recognize the formal distinction between Sacred Scripture and its interpretation, and this led them unduly to transpose into the realm of the doctrine of the faith a question which in fact pertained to scientific investigation."

John Paul's apology did not satisfy everyone. But major newspapers interpreted the pope's speech as an exoneration of Galileo. Time will tell how well the speech will serve John Paul's stated aim—dispelling the fog of mistrust that still obscures relations between scientists and the church.

—Steven Gertz

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A God of Math & Order

The new science rode in on the shoulders of theological ideas.

Peter Harrison

What caused the scientific revolution? How did science advance from the relatively static medieval philosophies of nature to the dynamic technologies of modern science? Secular historians have argued that the church opposed this progress at every turn. But in fact a set of new theological ideas ushered in the scientific innovations of men like Galileo, Descartes, and Newton.

First, Christian thinkers applied God's sovereignty to the natural realm in a new way, asserting that nature was governed by God-designed mathematical laws. Then, concerned to protect that sovereignty against Aristotle's notion that natural entities possessed intrinsic drives, Christians began to strip nature of her divinity, positing instead mechanical processes.

"Laws he himself fix'd"

*Nature and Nature's laws lay hid
in night
God said: "Let Newton be!"
and all was light.*

Alexander Pope's famous couplet gives the impression that Newton's genius lay in his discovery of previously hidden laws of nature. This disguises what was both a novel feature of the science of the seventeenth century and its enduring legacy—the idea that there existed "laws of nature" to be discovered in the first place.

What are laws of nature? For the Middle Ages, natural laws had been universal moral rules established by God. The injunction against murder, recognized by all cultures, was a typical example of a natural law. The concept of a physical law of nature was completely absent. That came only as Christian thinkers extended God's legislative power to the natural world. As philosopher and scientist René Descartes (1596-1650) expressed it, "God alone is the author of all the motions in the world."

For its time, this was a radical claim. Following Aristotle, medieval scientists had imputed immanent tendencies to physical entities, saying for example that objects went into motion because they were seeking their own natural resting place. Nature had thus enjoyed a considerable degree of autonomy.

In the new science, however, natural objects had no inherent properties, and it was God who directly controlled their interactions. In much the same way that the Deity had instituted moral rules, he was now seen to have enacted laws that governed the natural world.

"Nature," observed Robert Boyle, "is nothing else but God acting according to certain laws he himself fix'd."

The fact that God was the author of these laws meant that they shared something of his nature. Descartes, for example, argued that because of their source, natural laws must be eternal and unchanging. He went on to justify his law of the conservation of motion by appealing to God's immutability. Nature was constant because God was immutable.

This provided a crucial foundation for experimental science. In the words of Newton's predecessor in the Lucasian Chair of Mathematics at Cambridge, Isaac Barrow, experimentalists "do not suspect that Nature is inconstant, and the great Author of the universe unlike himself." Only because they assume that God's decrees are unchanging do they expect the consistent results of a number of experiments to hold true ever after.

The mathematics of Nature

The idea of eternal and immutable laws of nature, vital to modern science, found a close ally in mathematics. A distinguishing feature of science, as many hapless students have discovered to their regret, is its mathematical character. But this had not always been so. This change, too, emerged from theology.

To medieval thinkers, the marriage of mathematics and natural science would have been an illicit and barren union. Following Aristotle, they held mathematics to be a product of the human mind. For this reason mathematics was not thought to provide true descriptions of reality: useful descriptions—yes—but not true descriptions.

Astronomers, regarded as practitioners of a mathematical science, were thus thought to trade in useful fictions. Their models were capable of predicting the positions of heavenly bodies but were not thought to provide a true physical account of the cosmos.

This very issue led to Galileo's fateful encounter with the Inquisition. He insisted that the sun-centered system of Copernicus was more than a useful mathematical device—it was an accurate physical description. Galileo's novelty, then, lay in his championing not of a new astronomical model, but of a new model of astronomy.

Mathematics could provide a true account of the universe only if it were more than a human construction. Galileo, Kepler, Descartes, and Newton made the bold assertion that mathematical relations were real only because they were convinced that mathematical truths were the products not of human minds, but of the divine mind. It was God who had invented mathematics and who had imposed mathematical laws on the universe. Like Scripture, the "book of nature" had also been written by God, and, as Galileo insisted, this book was "written in the language of mathematics."

Descartes cited the inter-testamental book, Wisdom of Solomon, to support his contention that God was a mathematician, "Thou hast ordered all things in measure and number and weight" (11:20). Newton subsequently described the cosmos in terms of an "infinite and omnipresent spirit" in which matter was moved by "mathematical laws."

Crediting God as the author of mathematics was thus a crucial step in asserting the reality of mathematical relations, and this enabled the subsequent application of mathematics to the field of physics.

The atom and God's machine

Consistent with their belief in divinely-imposed laws of nature, the new cadre of Christian scientists jettisoned Aristotle's notion that changes in the behavior of material things derived from a "final cause" that drove them to fulfill their natural functions. In its place they developed atomic matter theory and the idea of nature as a vast machine, running smoothly according to God's mathematical laws.

A number of seventeenth-century thinkers revived the ancient Epicurean view that all matter was made up of minute particles that were qualitatively identical. The various interactions of matter were to be accounted for not by inherent virtues and qualities, but by the motions and collisions of the various

particles. Thus heat, once regarded as a quality inherent in an object, could now be explained quantitatively in terms of the motions of its particles.

This new theory of matter had momentous implications. One was that matter's microscopic components could be explained by the laws of nature. Just as motions in heavenly bodies were described in terms of mathematical laws, so too were motions of atomic particles. In this manner, the government of matter came under the direct jurisdiction of God.

The "final causes," which Aristotle had located within nature itself, were now understood as God's externally imposed purposes.

God thus was seen to be more intimately involved in the operations of nature than he had been before. This motivated the quest to discern divine purposes in the natural world.

Each of these developments reflects a renewed emphasis on the sovereignty of God. This paralleled the change in the theology of justification. Just as the new scientists stripped natural bodies of their inherent causal virtues, Protestant Reformers insisted that human virtues could not achieve, or cause, justification. The whole initiative lay with God, whose eternal decree determined who would be justified. In theology as in nature, all ran according to God's unchangeable laws.

Could modern science have arisen outside the theological environment of Western Christendom? It is hard to say. What is certain is that it did arise in that environment, and that theological ideas underpinned some of its central assumptions.

Those who argue that science and religion are at odds will draw little comfort from history. When modern science assumes mathematical laws and the constancy of nature—assumptions essential to its development—it echoes the theological presuppositions that attended its birth.

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CHRISTIAN HISTORY

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Luminous Wonder, Heavy Cross

A sense of cosmic awe sustained Johannes Kepler through deep sorrow.

Joseph L. Spradley

On an unforgettable night in 1577, a mother took her 5-year-old son to the top of a hill to view the bright path of a comet. The boy was Johannes Kepler (1571-1630), and that night his life course was set.

The reverent wonder of that experience shines from Kepler's later description of Copernicus's cosmology—which he was the first to publish in textbook form.

Kepler imagined the heliocentric universe as a reflection of the Trinity: The sun at the center represented God the Father, the outer sphere of stars represented Jesus Christ, and the intervening space represented the Holy Spirit.

This vision of the stars as a window into the eternal sustained the Lutheran astronomer through a life of unremitting suffering.

His father, a mercenary soldier, went missing in action when Johannes was 16. Kepler's first wife died, and he lost several children from both his first and second marriages. He was persecuted by the Catholic Church and excommunicated from the Lutheran church over views of the Lord's Supper that were later changed. He endured the death from drink of his employer and mentor, Danish astronomer Tycho Brahe; the descent into madness and death of his patron, the Holy Roman Emperor Rudolph II; and the arrest and threatened torture (which his intervention averted) of his mother for the crime of witchcraft.

Schooled not only in mathematics and astronomy but also in theology, Kepler initially intended to serve as a minister. However, in 1594 Lutheran authorities assigned him a job as a mathematics teacher in Graz, Austria. There his duties included compiling an annual calendar of astrological predictions, which he did with reluctance and cautious generality.

In 1596, Kepler published his *Cosmographic Mystery*, on the spacing of the planetary orbits. On the eve of its publication, he wrote to his astronomy teacher at the university of Tübingen, Michael Maestlin, "I am devoting my effort ... for the glory of God, who wants to be recognized from the Book of Nature."

Kepler's efforts produced their most famous fruit in his first two laws of planetary motion, published in his 1609 masterpiece, *The New Astronomy*, and his third law of planetary motion, discovered in 1618. These laws set the stage for the emerging scientific revolution. Fifty years later, Isaac Newton's search for an underlying explanation for Kepler's laws led him to formulate his own law of universal gravitation.

Kepler followed up *The New Astronomy* with his *Epitome of Copernican Astronomy* (1616). He sent a copy to Galileo, who responded that he had been a secret Copernican for several years and was collecting physical proofs of the earth's motion.

Johannes Kepler died in Regensburg on November 15, 1630, and was buried in the Protestant cemetery. As if God was honoring the astronomer's lifelong dedication to glorifying Him through the study of the stars, several witnesses reported that fireballs—now known as meteors—fell from heaven that evening.

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Did the Reformers Reject Copernicus?

Some defenders of secular science say they did. What's the real story?

Owen Gingerich

From the start, Nicolaus Copernicus's heliocentric system, described in his *De Revolutionibus*, met opposition from Catholics and Protestants alike. Critics attacked his new cosmology with a number of Scripture passages:

Psalm 19: "He set the tabernacle for the sun, which is as a bridegroom coming out of his chamber, and rejoiceth as a strong man to run a race. His going forth is from the end of the heaven, and his circuit unto the ends of it."

Psalm 93: "Thou hast fixed the earth immovable and firm, thy throne firm from of old."

Ecclesiastes 1: "But the earth abideth forever. The sun also ariseth, and the sun goes down, and hastens to his place where he arose."

In 1539, even before Copernicus's book was printed, Martin Luther had already heard about the astronomer's theories—and commented against them in the course of a dinner conversation. An eager young student copied down the critique and reported it:

"There was mention of a certain new astrologer who wanted to prove that the earth moves and not the sky, the sun and the moon. This would be as if somebody were riding on a cart or in a ship and imagined that he was standing still while the earth and trees were moving. Luther remarked, 'So it goes now. Whoever wants to be clever ... must do something of his own. This is what that fellow does who wishes to turn the whole of astronomy upside down. ... I believe the Holy Scriptures, for Joshua commanded the sun to stand still, and not the earth.'"

Another student recorded it a little differently: "That fool would upset the whole art of astronomy." A punchier "sound bite," this version has been widely quoted, though scholars generally believe it to be apocryphal.

These off-the-cuff remarks might have been forgotten, though they were printed in the *Tischreden* or "Table Talk" series, first published in Wittenberg in 1566. But Luther's comments gained notoriety when Andrew Dickson White, first president of Cornell University, polished them up in 1896 as part of his *History of the Warfare of Science with Theology in Christendom*.

A liberal Christian, White's announced goal was to let "the light of historical truth into that decaying mass of outworn thought which attaches the modern world to medieval conceptions of Christianity—a most serious barrier to religion and morals." He was eager to discredit what he believed was religion's antipathy toward the march of science, so he got his graduate students to dig up as many cases as they could find.

The former Cornell president was not about to stop with Luther. Despite the fact that Copernicus's book was essentially published under Lutheran auspices, White continued, "While Lutheranism was thus condemning the theory of the earth's movement, other branches of the Protestant Church did not remain

behind. Calvin took the lead, in his commentary of Genesis, by condemning all who asserted that the earth is not at the center of the universe. He clinched the matter by the usual reference to the first verse of the ninety-third Psalm, and asked, "Who will venture to place the authority of Copernicus above that of the Holy Spirit?"

White's quotation set historians off on a frustrated search to find where the Genevan reformer mentioned Copernicus. Copernican scholar Edward Rosen, a master of minutiae, tracked down a flock of authors who simply parroted White's account, but traced the comment itself back to Rev. F. W. Farrar, an Anglican canon who was at one time chaplain to Queen Victoria, and who over-confidently relied on his capacious memory of quotations to generate out of whole cloth Calvin's comment on Psalm 93. Rosen concluded that Calvin had never heard of Copernicus, let alone critiqued him.

There the matter stood until 1971, when a French scholar noticed that in a sermon on 1 Corinthians 10 and 11, Calvin denounced those "who will say that the sun does not move and that it is the earth that shifts and turns." Here, however, Calvin neither mentioned Copernicus by name, nor did he invoke any Scripture against heliocentrism itself. In fact, it has been cogently argued that Calvin was alluding to a quotation in Cicero brought on by a debate with one of his understudies who had fallen out of his good favor. So the jury is still out on Calvin's opinion, if any, on Copernicus and his book.

Given the wide distribution of *De revolutionibus*, it seems likely that John Calvin saw the book. But he probably also joined many of his devout contemporaries in viewing it as a mathematical device for calculation rather than a real description of nature. Indeed, a notice to readers had been added to the back of the book's title page that insisted on just this point.

When Copernicus's friend Bishop Tiedemann Giese saw the unauthorized addition, however, he angrily fired off a letter to the Nuremberg City Council demanding that the front matter be printed again. Giese then asked Copernicus's first and only disciple, the Lutheran scholar Georg Joachim Rheticus, to insert in the copies not yet sold a short apologia "by which you have so skillfully defended the idea that the motion of the earth is not contrary to the Holy Scriptures."

What was it that young Rheticus might have said to introduce Copernicus's work to a flock of readers with their varying Protestant or Catholic orientations? Neither most of his contemporaries nor Andrew Dickson White ever knew. Only in the flurry of research associated with the 1973 celebration of Copernicus's birthday did Rheticus's treatise surface. It had indeed been printed, but anonymously, in a booklet published in Utrecht in 1651. It languished in obscurity until it was identified by the Dutch historian of science Reijer Hooykaas.

Rheticus listed many places where the Bible could not be read literally. He then cited a series of passages commonly used to condemn the reality of the heliocentric plan, including Joshua and the battle of Gibeon, and concluded by remarking that common speech mostly follows the judgment of the senses. "As persons who seek the truth about things," he wrote, "we distinguish in our minds between appearance and reality."

The future of Protestant response to Copernicus clearly lay with Rheticus, rather than with the off-hand remarks attributed to Luther.

Contrary to the polemics of Andrew Dickson White and others in his secularizing tradition, many Christians—Protestant and Catholic alike—who valued the authority of the Scriptures nevertheless saw that they had not intended to provide literal scientific information. In the famous words quoted by Galileo in his "Letter to the Grand Duchess," the Holy Spirit intended the Scriptures to show not "how heaven goes," but "how one goes to heaven."

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Interior Design

16th-century students of anatomy saw the hand of God in the intricacies of the body.

James D. Smith III

Nicolaus Copernicus's re-mapping of the macrocosm wasn't the only sixteenth-century breakthrough on a scientific frontier. Equally stunning was a bold trek into the microcosmic world of our physical selves.

This voyage, led by the anatomist Andreas Vesalius (1514-1564), seemed to bring humankind into a new and intimate knowledge not just of our physical being, but of our spiritual being as well.

Born in Brussels, Vesalius likely received his elementary education from the Brethren of the Common Life, a Roman Catholic spiritual association that trained Thomas à Kempis and Desiderius Erasmus. His studies took him from the great universities at Louvain and Paris to that at Padua, which appointed him professor of anatomy and surgery the day after he received his M.D. in 1537.

While at Louvain, Vesalius had participated in one of his first human autopsies, an event that set the course of his future research. The ancient anatomist Galen—rediscovered in the Renaissance—had derived his human anatomy from observations of animal subjects. But in his 1538 manual ***Six Anatomical Tables***, Vesalius proclaimed a new method: researchers of human anatomy should dissect and observe actual human subjects, and develop terminology and illustrations to match their observations.

After 1539, Vesalius performed a series of dissections—usually on cadavers of criminals or indigents, or members of dedicated patron families. He recorded some of the results of these and sketched them for detailed rendering in the lavish woodcuts of his ***Fabric of the Human Body*** (1543).

Some anatomists reacted harshly, defending Galen. But most church leaders received Vesalius's findings without a murmur. (In fact, a notable 1540 dissection had taken place in Bologna's Church of San Francisco.)

When we read ***Fabric***, we begin to understand this favor of the church. In the first chapter, Vesalius exults over the created wonder of bones: "God, the supreme Architect, in his wisdom formed material of this temperament, placing it beneath the surface as a foundation for the whole body." In Book II, he urges his reader to "sing hymns to the Creator of the world, who produced from such a tiny space [the jaw muscle] in charge of such an important task." In Book VI, he passes over the question of why so much water flowed from the side of the crucified Jesus, "for I must not in the slightest degree upset the complete veracity of the authentic Gospel of John."

Vesalius's theologically informed approach to anatomy was not unusual in his time. Many sixteenth-century researchers studied the body to gain insight into the soul. Indeed, anatomy entered the curriculum of Lutheran Protestant schools not through medical schools but as part of the study of philosophy. And the man who introduced anatomy to the University of Wittenberg's curriculum in 1535 was a theologian—Philip Melanchthon (1497-1560).

Melanchthon admired Vesalius's work and shared his sense that this new, inner frontier bore the stamp of divinity. The theologian wrote this poem in his copy of Vesalius's *Fabric*:

"Think not that atoms, rushing in a senseless hurried flight,
Produced without a guiding will this world of novel form;
The mind which shaped them, wise beyond all other intellects
Maintains and fashions everything in logical design ...

Accordingly it follows that the body's several parts
Came not together aimlessly as if devised by chance:
With purpose God assigned to each its own allotted task
And ordered that man's body be a temple to Himself ...

Wherefore as man reflects upon the marvels in himself,
With reverence let him venerate this Maker and his Lord,
And keep the temple undefiled, immune from any stain,
Lest wrath divine in vengeance come and hurl it crashing down."

In 1564, following two decades as imperial physician, Vesalius, the "father of modern anatomy," died during a pilgrimage to the Holy Land.

Another who delved deeply into the theological meanings of "the body's several parts" was Spaniard Michael Servetus (1511-1553). Servetus is usually seen by church historians in light of his 1531 book ***On the Errors of the Trinity***—in which Melanchthon found "many marks of a fanatical spirit." Historians of anatomy, on the other hand, cite his 1553 work, ***The Restitution of Christianity***. In this book Servetus, who had studied and gained favor from the same Paris anatomy professor as Vesalius, became the first person to describe the "pulmonary transit" of blood through the lung from the heart's right ventricle to the left auricle. However, this ground-breaking discovery remained unknown to medical contemporaries, as the book was read by few (none anatomists) before it was condemned and burned with its author on October 27, 1553 in Calvin's Geneva.

Obsessed with the oneness of God, Servetus used his medical studies to stretch the biblical idea of God's omnipresence beyond its traditional bounds. He came to believe not only that God was the creator and sustainer of the material world, but also that the very air one breathes is a form of God Himself. Thus to his notorious preaching against the Trinity he added what seemed to many Christians a pantheistic teaching.

Servetus wrote of "the divine philosophy which you may easily understand if you have been trained in anatomy." He read in the body the structures and pathways of the Spirit, declaring "The matter of the soul (***anima material***) is made from the blood of the liver ... the soul itself is the blood. ... For the soul is not said to be principally in the walls of the heart or in the body of the brain or of the liver, but in the blood, as God Himself teaches in Genesis 9, Leviticus 17 and Deuteronomy 12."

Though each read it differently, Vesalius, Melanchthon, and Servetus joined others of their time in "returning to the text"—the text of the human body—in search of Truth both scientific and spiritual.

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The Christian Face of the Scientific Revolution: Christian History Timeline - Milestones to Modern Science

Medical and Biological Science

- 1543** Andreas Vesalius publishes unprecedented observations about the human body in *De Fabrica*.
- 1546** Girolamo Fracastoro proposes the idea that diseases can spread like seeds.
- 1599** Ulisse Aldrovandi publishes the first textbook of zoology.
- 1628** William Harvey publishes his work describing the blood's circulation and the heart's structure.
- 1650** Antony van Leeuwenhoek creates a microscope ten times more powerful than previous models.
- 1663** Robert Hooke discovers cells in a section of cork using a microscope.
- 1668** Francesco Redi disproves theories of spontaneous generation.
- 1674** Van Leeuwenhoek discovers bacteria using his microscope.
- 1701** Giacomo Pylarini gives the first smallpox inoculations to children in Constantinople.
- 1728** Pierre Fauchard describes how to fill teeth using tin, lead, and gold.

Astronomy

- 1543** Nicolaus Copernicus publishes *De Revolutionibus*, laying out his heliocentric theory.
- 1572** Tycho Brahe observes a supernova in the constellation Cassiopeia.
- 1596** Johannes Kepler writes the first public defense of the Copernican system.
- 1608** Hans Lippershey and Zacharias Janssen patent original versions of the telescope.
- 1609** Kepler publishes his first two laws of planetary motion.
- 1630** Galileo finishes his *Dialogue* and obtains permission for its printing from the Vatican.
- 1688** Isaac Newton builds his first reflecting telescope.

Physics and Chemistry

- 1591** Galileo demonstrates that the rate of a falling object does not depend on its weight.

1600 William Gilbert suggests the Earth behaves like a giant magnet with poles on opposite ends.

1649 Pierre Gassendi revives the idea that matter is made up of atoms.

1650 Otto von Guericke's air pump creates a vacuum between two hemispheres that even teams of horses can't pull apart.

1660 Royal Society founded

1687 Newton publishes his three laws of motion and the law of universal gravitation.

1704 Newton combines mathematics and experiments in his particle theory of light.

World Events

1517 Martin Luther posts his ninety-five theses.

1555 Peace of Augsburg allows German rulers to determine their regions' religion.

1582 Pope Gregory XIII authorizes the calendar's reform based on Copernicus's theories.

1588 Britain defeats the Spanish Armada.

1611 King James Bible published

1618-1648 The Thirty Years War

1620 Pilgrims land at Plymouth.

1649 Charles I of England is beheaded by Oliver Cromwell.

1692 Witch trials held in Salem, Massachusetts.

1738 John and Charles Wesley experience their evangelical conversions.

A Priest Serving in Nature's Temple

Robert Boyle's career blended faith, doubt, and the use of science to heal disease and fight atheism.

Edward B. Davis

It was truly a dark and stormy night. An adolescent boy, deep asleep, was jarred awake by the concussion of thunder right overhead. Lightning repeatedly ripped the sky outside his window. He was terrified.

The flaming night pressed in on his imagination until he saw himself standing, on judgment day, amid the final conflagration that would consume the world. He trembled at the thought that he was not prepared to face that day, and he resolved to live for God. Robert Boyle kept that vow throughout his life. He dated his conversion from that awful night.

Within months, however, his faith came under attack. During a casual visit to the original Carthusian abbey of Grande Chartreuse in "those Wild Mountaines" near Grenoble, as Boyle described them in a memoir, he became deeply depressed. There, "the Devil taking advantage of that deepe, raving Melancholy, [and] so sad a Place" planted in his mind "distracting Doubts of some of the Fundamentals of Christianity." Boyle even contemplated suicide, drawing back only for fear of committing such a dreadful sin. Only after "a tedious languishment of many months" did it please God to "restore unto him the withdrawne sence of his Favor."

Religious doubt would henceforth be a defining characteristic of Boyle's personality, yet it played a positive role in the construction of his deeply thoughtful, charitably irenic faith.

His approach to doubt—the other side of the coin of faith—was frankly precocious. Just three months after his twentieth birthday, he wrote, "He whose Faith never doubted, may justly doubt of his Faith." Throughout his life, Boyle cultivated an active yet reflective piety. Daily he sought God in the pages of Scripture and investigated His wondrous works for the benefit of others.

Today, Boyle appears in high school chemistry courses as the scientist who formulated "Boyle's Law," describing the inverse relation between the pressure and volume of gases. Because of his many important discoveries, Boyle has been tagged "the father of chemistry."

What is absent from this image is the deeply religious man who wrote as much about God as he did about the nature of air; the man who considered himself a "priest" in the "temple" of nature; the man who paid for translations of the Bible into Gaelic and into the language of the Indians in Massachusetts.

Mary, Kate, and Robyn

Boyle's upbringing did not point him clearly either to science or to deep piety. Born in January 1627, he was the seventh son and fourteenth child of Richard Boyle, the first Earl of Cork, an unscrupulous man who took advantage of English colonialism in Ireland to become one of the wealthiest men in the realm.

Young "Robyn," as he was called, watched as his thirteen older brothers and sisters became pawns in a game of power, the boys given titles and lands and the girls married off to the sons of other powerful men—who usually had more love for their houses and horses than for their wives.

Robyn, however, declined a title and took a dim view of courtly mores. He narrowly avoided an arranged marriage himself, remaining celibate his entire life.

Although she was twelve years older, his sister Katherine became Robyn's closest confidant. A brilliant woman, she convened a salon for important intellectuals, including John Milton and several members of Parliament. Robyn lived in Katherine's London home for much of his adult life. She was also deeply pious and well versed in theology. Robyn, Katherine, and another illustrious sister, Mary Rich, Countess of Warwick, joined regularly in uplifting conversation—as Mary wrote in her diary, "good and profitable discourse of things wherewith we might edify one another."

Boyle's earliest writings reflect the intensity and intimacy of his relationship with God. These include two essays on the spiritual damage done by swearing, an ethical treatise influenced by Erasmus, and various essays, reflections, and romances (fictitious narratives) on moral and religious subjects.

One of Boyle's religious works, *Occasional Reflections Upon Several Subjects*, gained great popularity among the Puritans and remained in print for almost two hundred years.

Science next to godliness

It was only after writing such works as these that Boyle decided to take up serious scientific study. Although always profoundly curious about the natural world, he was even more strongly motivated by a desire to improve the human condition and to alleviate suffering. From early in his career he applied chemical knowledge to medical problems, publishing recipes for medicines in order to make such cures more widely available to the poor. (In this he anticipated by a century another "minister of medicines"—John Wesley.)

Once Boyle began to investigate nature, he never slackened. His Christian convictions gave these scientific pursuits an unanticipated boost: Science has always involved groups of people working together toward common goals. Boyle's unquestioned honesty, unflinching charity, and genuine interest in the public welfare made him an excellent colleague. Soon his integrity and warmth helped him gain entrée to an important community of "gentlemen," who met regularly in Oxford to view experiments and to discuss the latest scientific discoveries and ideas. In 1660, Boyle joined with a number of these men to found the Royal Society, the first scientific organization in the English-speaking world.

The next dozen years were the most productive of his life, earning him a worldwide reputation as the outstanding experimental scientist of his generation. His most famous contributions involved the use of an air pump, expertly made for him by Robert Hooke, a brilliant Oxford student who went on to become a great scientist himself. With this apparatus, Boyle demonstrated several properties of the air, confirming in clear, clever ways the hypothesis of Blaise Pascal and others that the atmosphere is a vast fluid like the ocean. Just as water pressure increases with depth, so too air pressure, Boyle showed, depends on the height of the atmosphere.

Other experiments, with insects and small mammals, clarified the connections among respiration, combustion, and various components of the air.

Atoms vs. idols

In his subtle book on the doctrine of creation, *A Free Enquiry Into the Vulgarly Receiv'd Notion of Nature*, Boyle argued that the new science had its theological uses. The prevailing "vulgar" (popular) concept of nature, derived from the Greek scientist Aristotle and the Roman physician Galen, tended to personify nature. Statements, for example, that "nature abhors a vacuum" or that "nature does nothing in vain" Boyle considered idolatrous, since they effectively placed an intelligent, purposive agent, "much like a kind of *Goddess*," between God and the world God had made.

Noting that the Old Testament contained no "word that properly signifies **Nature**, in the sense we take it," Boyle argued for what he called the "mechanical philosophy," which explains natural phenomena from the purely mechanical properties and powers given to unintelligent matter by God at the creation. Such an approach, he believed, more clearly underscored the sovereignty of God and located purpose where it properly belonged: in the creator's mind, not in some imaginary "Nature."

Boyle also advocated the argument for the existence of God from signs of design in nature. Indeed, he had a strong interest in apologetics generally, reflecting his lifelong conversation with his own religious doubts. He wrote extensively on apologetic themes and in his will established a lectureship for "proving the Christian Religion against notorious Infidels (viz) Atheists, Theists [that is, deists—people who believed God created the world, then stepped aside], Pagans, Jews and Mahometans."

Although he often targeted "atheists" in his writings, he realized that genuine philosophical atheism was rare in his day. He was actually more concerned with what he called "practical atheists"—those "baptised infidels" who lived as if there were no God to judge them—and here he thought the design argument had its greatest value.

As he wrote in *Disquisition about the Final Causes of Natural Things*, Boyle wanted his readers not to "barely observe the Wisdom of God," but to be emotionally convinced of it. And what better to instill "wonder and veneration" in people than to show them the "Admirable Contrivance of the Particular Productions of [His] Immense Wisdom"? He had in mind especially the exquisitely fashioned parts of animals. Thereby, Boyle believed, "Men may be brought, upon the same account, ... to **acknowledge** God, to **admire** Him, and to **thank** Him."

Shortly after midnight on the final day of 1691, Robert Boyle died in the house of his beloved sister Katherine. She had died herself just eight days before; grief likely hastened his own passing, although he was never robust and had been in declining health for several years.

Boyle was laid to rest close to Katherine in the chancel of their parish church, St. Martin-in-the-Fields. The precise location of his grave is no longer known. Given the humility he maintained throughout his illustrious life, we may easily imagine that Robert Boyle would be pleased with this final anonymity.

Edward B. Davis is Distinguished Professor of the History of Science at Messiah College. This article is adapted from a chapter in Reading God's World: The Vocation of Scientist, ed. Angus Menuge (Concordia, 2003). Readers of this article might also be interested the following article by Edward B. Davis, "Robert Boyle's Religious Life, Beliefs, and Vocation." Science & Christian Belief 19.2 (2007): 117-38.

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CHRISTIAN HISTORY

Issue 76: The Christian Face of the Scientific Revolution

Newton vs. Newton

Mark Galli

"Atheism is so much the worse that it is not buried in books," worried Richard Bentley in an early Boyle lecture, "but is gotten [into life], that taverns and coffee-houses, nay Westminster-hall and the very churches, are full of it." This invidious "atheism" so troubled Robert Boyle that his will provided for a lectureship "for proving the Christian Religion, against notorious infidels, viz. Atheists, Theists, Pagans, Jews, and Mahometans. ..."

By "atheists" Boyle and his theological allies meant a growing attitude, not merely the formal denial of the existence of God. They fought the claims that this diffuse atheism spawned: that the foundation of the world is material, that there is no immortality of the soul, that the Bible is not divinely inspired, that there is no absolute morality, and so forth.

The title of Bentley's opening lectures in 1692—*The Folly and Unreasonableness of Atheism Demonstrated from The Advantage and Pleasure of a Religious Life, the Faculties of Human Souls, The Structure of Animate Bodies, & The Origin and Frame of the World*—announced the foundation of their apologetic: Newtonian science.

Evidence exists, in fact, that Newton helped Bentley think through his lecture. Newton wrote in one letter, "When I wrote my treatise about our Systeme, I had an eye upon such Principles as might work with considering men for the beliefe of a Deity & nothing can rejoyce me more than to find it usefull for that purpose." Thus the lecture became the first popular expression of Newton's *Principia*.

The Boyle lecturers also fought on another front. Deists used the very same Newtonian ideas to remove God from the world and spoke of a nature of impersonal laws. The lecturers were anxious to prove that Newton's theories *required* God's direct involvement.

"There is no such thing as what men commonly call the course of nature, or the power of nature," said Samuel Clarke in one lecture. "[It] is nothing else but the will of God producing certain effects in a continued, regular, constant, and uniform manner."

The lectures became not only an influential apologetic for the Christian faith, but also a popular justification for the standing social order. The same Providence who generates the laws of the universe also oversees the workings of society, some lectures argued—thus there is a natural social order, with natural leaders. Men not only must conform to their station in life, but they should shape political and economic life to conform to the stability and harmony decreed by God. Such reasoning attacked thinkers like Thomas Hobbes, who sought social harmony (i.e., justice) through revolution.

Eventually, the first 40 years of lectures were published, which caused these ideas to be discussed all over Europe. Today the lecture series continues, but hardly anyone has heard of it. In the eighteenth century, however, no lectureship was more influential.

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Quotable Boyle

(Robert Boyle quotes)

Robert Boyle was not only a brilliant and innovative scientist, but also an accomplished writer on religious subjects. Puritan preacher and theologian Richard Baxter once wrote warmly to Boyle, "Your pious Meditations & Reflections, do call to me for greater Reverence in the reading of them, & make me put off my halt, as if I were in the Church."

What so affected Baxter? No doubt it was Boyle's deep piety, as seen in statements such as these:

"He that made our Souls, and upholds them, can best know what they are, and how long he will have them last."

—*The Excellency of Theology* (1674)

"We must never venture to wander far from God, upon the Presumption that Death is far enough from us, but rather in the very height of our Jollities, we should endeavour to remember, that they who feast themselves today, may themselves prove Feasts for the Worms tomorrow."

—*Occasional Reflections Upon Several Subjects* (1665)

"He whose Faith never doubted, may justly doubt of his Faith."

—*Diurnall Observations, Thoughts, & Collections* (1647)

"The book of nature is a fine and large piece of tapestry rolled up, which we are not able to see all at once, but must be content to wait for the discovery of its beauty, and symmetry, little by little, as it gradually comes to be more and more unfolded, or displayed."

—*The Christian Virtuoso*, in Thomas Birch, ed. *Works* (1744)

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Creation's Symmetries, God's Mystery

Blaise Pascal pioneered in math and physics but drew faith from revelation alone.

George Murphy

Pascal today means a unit of pressure, a computer language, a law in fluid mechanics, and an array of numbers with certain properties.

Few who use his name in these ways know that Blaise Pascal was also a devout Christian and a profound apologist for his faith.

In 1623, Pascal was born into a world that had recently seen the Reformation, the Counter Reformation, and the beginnings of modern science. The Thirty Years War began five years before Pascal's birth, and he was ten when Galileo was forced to recant his teaching of the Copernican system.

Studying under his father, a civil servant, the precocious Pascal first displayed his talents at 16 with his "mystic hexagon" theorem, noting special qualities of a hexagon inscribed in a circle. This he followed with a book on geometry that some contemporary mathematicians refused to believe a teenager could have written.

At 19, he invented the distant ancestor of the modern computer—a calculating machine. Later, as he worked out answers to some friends' questions about gambling, the young genius founded probability theory.

Pascal added the physical sciences to his repertoire with experiments that expanded human knowledge of atmospheric pressure and the equilibrium of fluids. He was inspired to investigate these things by the invention of the barometer by a student of Galileo.

Pascal observed that mercury rises only thirty inches in a closed tube and saw that the space above the mercury challenged the old Aristotelian idea that "nature abhors a vacuum." His experiments on this phenomenon led him to conclude that a vacuum really did exist.

In defending this idea, he distinguished between the methods of science and those of theology. In the latter, said Pascal, tradition is the appropriate route to knowledge: we can't discover God scientifically. But neither can we learn from tradition how high a fluid will rise.

Indeed, he concluded, we should pity the blindness of those who bring authority alone as proof in physical matters, instead of reasoning or experiments; and we should abhor the wickedness of others who make use of reasoning alone in theology, instead of the authority of Scripture and the Fathers.

The night of fire

Pascal was on his way to a brilliant career as a mathematician and scientist when something more important intervened.

In 1646, after his father Etienne suffered a fall and was healed by the medical ministrations of two

devout doctors, Blaise joined other members of his family in identifying with the Jansenist movement.

Cornelius Jansen, Bishop of Ypres, had written a book on the theology of St. Augustine, which presented a rigorous view of Christianity. Its emphasis on predestination, the severity of sin, and complete dependence on God's grace seem at first glance close to Calvinism.

Nevertheless, the Jansenists intended to be loyal members of the Roman Catholic Church, and they followed Catholic teachings about church, ministry, and sacraments.

Pascal was not, however, influenced by doctrinal arguments alone. On the night of November 23, 1654, he had a powerful religious experience. He scribbled down a hasty account in what has been called "Pascal's amulet," which he carried in the lining of his coat until his death. Its words set out the heart of the faith he would defend:

FIRE

God of Abraham, God of Isaac, God of Jacob, not of the philosophers and savants
Certitude. Certitude. Feeling. Joy. Peace.
God of Jesus Christ.

* * *

Forgetfulness of the world and of everything except God
He is to be found only in the ways taught in the Gospel

* * *

This is life eternal, that they might know Thee, the only true God,
and Jesus Christ whom Thou hast sent

This "night of fire" had a profound impact. Pascal did not, however, see it as a private revelation that replaced or took precedence over the revelation to which Scripture bears witness.

It was an experience of the God of Israel, the One revealed in Christ. In his arguments for the truth of Christianity, Pascal never mentioned the night of fire: His "amulet" was found only after his death.

The Jansenists' strict views of Christian discipline and human incapacity to contribute to salvation set them at odds with the powerful Jesuits. Pascal's first theological writings, the *Provincial Letters*, were devastating attacks on the principles and policies of that order.

Pascal's most important contribution to Christian thought is the *Pensées*, the book that he was never able actually to write. It is a mark of Pascal's genius that his preparatory material could become such a classic.

Scholars have tried to reconstruct the work that Pascal projected. He was going to show first the wretchedness of humanity without God, and then the blessedness that is possible with the God who is known in Christ. This is a traditional approach, but Pascal's brilliance appears in the specific "thoughts" with which he intended to make these arguments.

"Only an occupation"

It is not true, as is sometimes said, that Pascal gave up mathematics after attaining his newfound faith. But during the last part of his life, he devoted himself to religious concerns, saying to his friend mathematician Pierre Fermat that geometry was "only an occupation," a dabbling in mundane things that pale in comparison to God's plan for the salvation of human souls.

We might expect Pascal to have much to say about relationships between science and religion, and perhaps to draw arguments from nature to demonstrate the truth of religion, as Newton and others would later do. But for Pascal, there is no way of knowing the true God apart from revelation—he found the argument from design unconvincing.

Those who seek God through nature, Pascal insisted in his *Pensées*, "either find no light to satisfy them, or contrive to find a way of knowing Him and serving Him without a mediator."

To Pascal, however, God is decidedly **not** absent in his world. Pascal reproached Descartes for what he saw as an effective deism, saying, "I cannot forgive Descartes. He would gladly have left God out of his whole philosophy. But he could not help making Him give one flip to set the world in motion. After that he had no more use for God."

What Pascal objected to was a natural theology that hinged on visible proofs. God is **hidden**—an idea that runs throughout the *Pensées*. Pascal argued with reference to Isaiah 45:15 ("Verily thou art a God that hidest thyself, O God of Israel, the Saviour" [KJV]) that what our eyes see in nature reveals "neither a total absence nor a manifest presence of the divine, but the presence of a God who conceals Himself."

The objection was prophetic. The natural theology of Newton and others led later generations to deism—the belief in a "clockmaker God" who creates the world but is not actively involved after that.

He bet his life on God

Though elsewhere he drew a sharp line between science and theology, Pascal's work on probability does lie behind his famous "wager." Either God exists or he does not, Pascal writes, and you must bet one way or another. If God exists, you could gain or lose infinite happiness. If God does not exist, then you could lose at most finite pleasure. "If you win, you win everything; if you lose, you lose nothing. Do not hesitate, then; gamble on His existence."

We may read in Pascal's life the signs of a man who bet his life on God. Compassionate as well as brilliant, he created the first public transportation system in Paris for the benefit of the poor. And in his own last illness, he gave his home over to a poor family stricken by smallpox.

In the end, Pascal left an example not only of how to think about Christianity, but also of how to live as a Christian.

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CHRISTIAN HISTORY

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Cosmic Codebreaker, Pious Heretic

Isaac Newton wrote theology and hoped his scientific theories would help people believe in God. But he harbored a deep secret....

Karl Giberson

Born prematurely on Christmas Day 1642, the year of Galileo's death, Isaac Newton was sickly and not expected to live. He spent the first few days of his life in a shoebox behind the woodstove. His father had died a few months earlier, and while little Isaac survived the sicknesses of infancy, he endured a series of childhood traumas, including abandonment by his mother to his grandparents, that left him withdrawn and solitary. Eventually he came to believe that thinking about nature was of far more importance than social distractions like marriage, children, or even friends.

As a young man, Isaac proved incompetent on the farm, once leading a bridle to the barn, unaware that the horse had escaped. Fences he was in charge of were always falling down, and court records chronicle numerous fines he received for allowing livestock to trample the neighbors' property.

More at home in the world of books, Isaac ended up in 1661 at Cambridge University, where the field hands on his farm had long said he belonged. He graduated without fanfare in 1665.

To escape the plague, he returned home for two remarkable years. Out of this brief seclusion came what was essentially a set of blueprints for changing the world: his theory of universal gravity and a number of major contribution to optics. But no one knew, yet, what the daydreamy young man was up to.

Newton returned to Cambridge University in 1667 and was soon, at age 26, Lucasian Professor of Mathematics. His star continued to rise as he made important scientific contributions, explaining everything from the motion of the planets, to the swing of a pendulum, to the formation of rainbows. Or at least explaining such things to himself, as the lectures he was required to give were often delivered to an empty hall.

After the publication of his notoriously difficult book known as the *Principia*, a Cambridge student pointed at him and said, "There goes the man that wrote a book that neither he nor anyone else understands."

Despite his general disinterest in explaining his ideas to the public, Newton's work greatly impressed his fellow members of the Royal Society, and by mid-career he became very famous. But he harbored a dark secret that had the potential to bring his rising star plummeting to earth.

Shortly after his widely acclaimed invention of both a remarkable telescope to collect light and an even more remarkable theory to explain light, Newton embarked upon a curious voyage of theological inquiry. The reasons remain hidden but were probably motivated by his impending need to be ordained in the Church of England, if he were to continue to hold the Lucasian Chair of Mathematics.

Whatever the reasons, Newton began a sustained reflection on the Christian doctrines and decided that the Anglican status quo was a thorough corruption of the true, original Christianity. These considerations led him to write over a million words on theology and biblical studies—more than he wrote on any other subject. Newton's theological investigations convinced him that the doctrine of the Trinity was bogus, a

successful deception by St. Athanasius in the fourth century. Newton argued that the Scriptures had been altered and early Christian writers had been misquoted to make it appear that Trinitarianism had been the original faith.

He became repelled by what he perceived as the false religion that surrounded him—an idolatrous faith that worshiped Christ as God, when he was but a mediator between God and man. Newton became convinced that the Roman Catholic Church, which had perpetrated the fraud, was the great whore of Babylon. To accept ordination into the Anglican Church would be to "worship the Beast and his image and receive his mark."

So Europe's greatest scientist began to make plans to be unemployed. In January 1675 Newton wrote to the Royal Society asking them to suspend his dues, anticipating that he would soon be unable to pay them. Newton's prestigious Cambridge University chair was located at Trinity College, no place for a Unitarian. Politics, however, allowed him to keep his post. Being the most famous scientist in the world had its perks.

Though Newton was far from orthodox, he was deeply religious in a number of important ways. He had been involved in distributing Bibles to the poor. More important was the way he attempted to reconcile his science with his religion. Newton and the Rev. Richard Bentley (1662-1742) exchanged a number of letters on whether the universe, as disclosed by the new physical theories, evidenced design. In one of these letters Newton wrote, "I had an eye upon such Principles as might work with considering men for the belief of a Deity."

A popular misconception is that Newton espoused a purely mechanical model of the universe, theologically deistic, requiring of God nothing more than pushing the "start" button. While this is the way things unfolded over the next century, Newton was in no sense a deist. In fact, as is often the case with the founders of great traditions, Newton was not even a Newtonian. His work did lead to what became known as a mechanical description of nature, but this was far from how he saw it; tellingly, the French philosopher Descartes objected to Newton's model because it was not mechanical enough.

Newton's scientific contributions are spread across a number of important works, any one of which could have established his greatness. But it was the *Principia* that most elicited the awe of a generation of thinkers raised on the simple, earth-centered cosmos of Aristotle. It is here that we find the birth of the science of mechanics, that extraordinary union of pure mathematics and careful observation that became the model to inspire science for more than a century. Newton here communicated empirical observations about the natural world, like the fact that bodies of different weight fall at the same rates, in precise mathematical language. The achievement was unprecedented.

Newton changed not only our understanding of the world but also what we mean when we say that we understand the world.

He demonstrated that it was feasible to write accurate equations describing the force of gravity, without trying to explain just what gravity was. This mysterious gravity provided a mechanism to hold the stars in place—the prevailing view, going back to Aristotle, envisioned a set of nested glassy spheres that fixed the heavenly bodies in space. Gravity also explained the movements of objects on the earth and in space—previously, most folk had believed material things were literally "motivated" by innate drives. Gravity kept the planets orbiting regularly about the sun. It held the atmosphere of the earth in place while it hurtled around the sun at what must have seemed, to the horse-riding residents of the seventeenth century, an unthinkable speed (now known to be about 67,000 mph).

But the concept of gravity was hard for Newton's contemporaries to swallow; it seemed a quintessential example of the occultic phenomenon of "action at a distance." To suggest that the earth reached out through empty space and "pulled" on the moon was to speak nonsense, regardless of the mathematical

precision of Newton's explanation. But somehow, as if he alone still heard the faint music of Pythagoras, Newton knew that God was a mathematician, and that this was the character of the world.

While the *Principia* is primarily a work of mathematical physics, there are some interesting theological interludes. In the second edition of the *Principia*, Newton suggests that comets might refuel the sun, replenishing the energy lost illuminating the earth. Newton's intuition, informed by his concept of God's providence, suggested to him that the God-given purpose of comets in the creation was to keep the sun healthy. Such speculation, while consistent with Newton's view that God sustains the universe at all times, still stands out against what is otherwise a much more straightforward scientific approach.

The last part of the *Principia* is a "Concluding General Scholium," a short section written for the second edition to refute objections that the Cartesians had raised to the first edition. In many ways it is the most interesting part of the *Principia*. Here we find his oft-quoted coda:

"This most elegant system of the sun, planets, and comets could not have arisen without the design and dominion of an intelligent and powerful being ...

"He rules all things, not as the world soul but as the lord of all. And because of his dominion he is called Lord God Pantokrator. For 'god' is a relative word, and has reference to servants, and godhood is the lordship of God, not over his own body, as is supposed by those for whom God is the world soul, but over servants. The supreme God is an eternal, infinite, and absolutely perfect being: but a being, however perfect, without dominion is not the Lord God."

Many scholars have speculated about the significance of Newton's theological beliefs and any role they might have played in the development of his scientific ideas. The enthusiastic secularizers of the Enlightenment have dismissed his theological explorations as aberrations, the product of a great mind in decline. By contrast, contemporary creationists present Newton as one of their own, overlooking his considerable theological heresies.

Certainly, his search for a profoundly rational explanation for natural phenomena was fully consistent with his prior belief in the rational creator at the heart of the Judeo-Christian tradition. But to what degree did this creator inspire Newton's search for the hidden rationality of the world? To what degree was the rationality of the Creator derived from the rational substructure of the world, as disclosed in the work of Newton and those who followed him?

All we can say for sure is that Newton's theological affirmations and his scientific discoveries comfortably co-existed in his own understanding of the world. And Newton's understanding of the world, at the time that he lived, far surpassed that of any other human being on the planet whose motions he did so much to explain.

Sometime between 1:00 and 2:00 a.m. on March 20, 1727, Sir Isaac Newton died. He had suffered for some time with kidney stones, urinary incontinence, and gout. Less than three weeks earlier he attended his last meeting of the Royal Society. A week later he was laid to rest in Westminster Abbey, where his remains reside today.

In his *Memoirs*, Newton provides a self-portrait of his contribution to the world:

"I don't know what I may seem to the world, but, as to myself, I seem to have been only like a boy playing on the sea shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

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CHRISTIAN HISTORY

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The Christian Virtuosi

The Royal Society defended religion but laid the groundwork for irreligion.

Chris Armstrong

November 28, 1660, a group of English thinkers gathered at Gresham College, London, to hear a lecture by the young astronomy professor and future architect of St. Paul's Cathedral, Christopher Wren. As they talked among themselves after Wren's lecture, they agreed to form a society dedicated, as their full, official name later stated, to "Improving Natural Knowledge."

These charter members of the Royal Society felt that by joining forces, they could better promote the "New Philosophy or Experimental Philosophy" that had been the cause *célèbre* of English philosopher Francis Bacon (1561-1626). Gentlemen and scholars all, they called themselves "natural philosophers" or "virtuosi"—that is, lovers of learning. The word "scientist," though we use it here for the sake of convenience, was not yet current. It would be some 170 years before that term entered the English language, paralleling the term "artist."

During the century following the Royal Society's founding, England held an unrivalled position of influence in the European scientific community. Men like Robert Boyle and, later, Isaac Newton were recognized as the pacesetters of science.

The society's founding coincided with the Restoration of the English monarchy, and it brought together a mixed group of both Puritans and Anglicans. These Christians of opposing political and religious views would join in drafting and ratifying a charter that bid all members of the society to pursue the study of nature "to the glory of God and the benefit of the human race."

The Puritans among them, though they did not invent the experimental method, drew upon their iconoclastic roots in pursuing that method wherever it led. During the Interregnum, Puritan scientists had already contributed notable scientific advances. As historian Dorothy Stimson has put it, the same independence that had led them to challenge the authority of the pope in the Catholic Church and of the bishops in the Anglican Church now spurred these Puritan scientists on in their researching and theorizing—even when their results clashed with the accepted theories of such authorities as Aristotle and Galen.

The society enshrined this commitment to intellectual independence in its motto, *Nullius in Verba*, or roughly, "not bound to take anyone's word."

The Royalist Anglicans in the society also put their distinctive religious and political stamp on their science. The new science embedded law in nature itself, and these men developed arguments from the lawfulness of the natural world in support of king, church, and economic institutions.

The ranks of the early Royal Society's "natural philosophers" included many men of substantial means who indulged in a popular hobby of the rich: collecting curiosities—some scientifically significant, but many not. One such collection, bestowed on the society in its early years by one of its fellows, included "a wind-gun, a burning-glass in a brass frame, a piece of petrified wood, a cocoa-nut, an ostrich's egg-shell, a strange bone with a rib in the middle," and "two papers of petrified grass."

More seriously, the society published a growing domestic and foreign correspondence "on Philosophical, Mathematical or Mechanical subjects," largely in its journal, the *Philosophical Transactions of the Royal Society*. This publication quickly became a cheerleader for the scientific revolution, as the society's meetings became its showcase. Also, in 1662 the society appointed a "curator of experiments"—the multi-talented Robert Hooke was the first—to make sure that every meeting had at least one experiment. From air pumps to blood transfusion, society fellows had the opportunity to see the inductive method in action and record its results.

Crowded around their compound microscopes, peering at fly eyes and plant seeds, the members shared the sentiments of their early presiding officer, John Wilkins, a bishop in the Church of England who wrote that the "admirable contrivance" and "accurate order and symmetry" of such natural objects revealed God's power and glory as much as did the books of the Bible.

The high hope of science with its Midas-like magic (and early members did often dabble in alchemy) seemed to promise every sort of improvement in the life of humankind. This promise did not escape the notice of king and government, who called upon the Royal Society repeatedly to help with various projects of national scope. These included the protection of buildings and ships from lightning, the ventilation of prisons, and the measurement of a degree of latitude.

Such prominence must have been exhilarating to members—the eclectic and even bizarre papers that showed up regularly at early meetings suggest that some members expected each new development to turn to gold before their eyes. "All things," perhaps, seemed possible for those who believed—in God, yes, but also in the new power science was placing in the hands of mortals.

From the first, many viewed the society askance. It seemed to some a rogue organization, not only threatening religion but also encroaching on the turf of venerable institutions such as the universities. Thomas Sprat wrote his *History of the Royal Society* (1667) as an official defense—the entire third part of the book answered the charge of atheism some opponents made against the society. He did this by listing fellows who were bishops and clergy, proof that the group posed no threat to established religion (Sprat himself was an Anglican priest).

But such maneuvers could not still the waves of criticism and downright ridicule. Famous authors such as Jonathan Swift joined the game, capitalizing on the public's skepticism by lampooning Royal Society members mercilessly in fiction and plays.

Nonetheless, the society grew in prestige—never more than when Isaac Newton ascended to its presidency in 1703, a position he would retain for 24 lively and productive years.

Newton's synthetic scheme of universal laws emanated, however, not only the rays of science's promise, but also the shadow of its peril. For along with new technologies, the members' scientific activities also gave life to an old idol: the remote, impersonal deity of the philosopher. Though the group proclaimed, and for the most part sincerely held, religious motives in its scientific work, the very fact of its religious diversity dictated a tolerant, broadminded view of the Christian faith—a view that would feed the irreligion many of them sought to combat.

For both pragmatic and pious reasons, some members of the Royal Society were influenced by the rationalist approach to religion urged by the Cambridge Platonists. In their public discourse they gravitated toward an essential Christianity that affirmed only the existence of God, the soul's immortality, and each person's ethical obligation to others.

Why did even deeply religious men use arguments that fed this lowest-common-denominator portrayal of their faith? As scientists who were Christians, but who taught a mechanistic universe that ran according to discoverable laws, they faced charges of irreligion themselves. They answered these

charges by insisting that the evidences of lawfulness and design in the fabric of things pointed not away from but toward God.

Little did these well-meaning men know, however, that the "rational religion" they erected as a broadly shared platform for scientific cooperation and a badge of their own orthodoxy would become in the next century a substitute for the Christ-centered teachings of the historic church.

As Blaise Pascal had worried, the virtuosi's oft-repeated argument from design eventually fed the eighteenth-century deists' creed of the distant "clockmaker God."

Chris Armstrong is managing editor of Christian History.

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Microscopic Magnificence

Antony van Leeuwenhoek found God's great glory in his tiny creations.

David F. Coppedge

During the last years of Antony van Leeuwenhoek's (say it "la ´vnhook ´") life, dignitaries from all over Europe, including Russian czar Peter the Great, King James II, and Frederick II of Prussia, visited his shop in Delft, Holland, to see the wonders revealed by his microscopes. But the Dutch cloth merchant seemed unaffected, retaining the delight of discovery that had first led him, at age 40, to focus a new lens on a world formerly unseen.

Until his death at 91, Leeuwenhoek spent his days grinding pinhead-sized lenses and peering through them, hour after hour, by candlelight. For this Christian layman-scientist, the astonishing array of tiny life-forms revealed under his homemade lenses glorified God as much as the brightest stars.

Born in Delft in 1632, Antony became a draper and only took up scientific studies as a hobby after seeing micrographs during a visit to London in 1660. He did not invent the microscope but took it to new levels of power. In the process he opened up to human eyes the world of microorganisms and founded a new branch of science: microbiology.

By 1673, Leeuwenhoek was discovering things with his superior microscopes that no human eye had ever seen. These he began sharing in letters to the natural philosophers of the Royal Society of London. The British scientists were at first skeptical of the claims by this untrained layman who spoke only Dutch.

When in 1676 he described finding microorganisms that were so small that "ten thousand of these living creatures could scarce equal the bulk of a coarse sand grain," they requested corroboration from other eyewitnesses. Several friends sent affidavits that they also saw these things through Antony's microscope. As Leeuwenhoek's observations were found to be accurate, his reputation grew, and by 1680 he was elected a fellow of the Royal Society.

Though he would never revisit London or attend a meeting, the amateur microscopist kept up a lively correspondence with the British scientists, who translated hundreds of his letters and published them in their *Philosophical Transactions*.

Leeuwenhoek's letters sparkle with the excitement of discovery. Describing the "wee animalcules" (protozoa and bacteria) he observed in a drop of fresh water, he wrote, "The motion of most of them in the water was so swift, and so various, upwards, downwards, and roundabout, that I admit I could not but wonder at it. I judge that some of these little creatures were above a thousand times smaller than the smallest ones which I have hitherto seen. ... Some of these are so exceedingly small that millions of millions might be contained in a single drop of water."

Leeuwenhoek investigated almost anything he could mount, exemplifying technical skill that would become a model for others. He was the first to observe bacteria, rotifers and protists like *Vorticella* and *Volvox*. He observed blood cells and was the first to see the whiplike action of sperm cells.

He advanced proofs against the doctrine of spontaneous generation that was popular in his day. This was the idea that living things emerge spontaneously from inanimate matter: shellfish from sand,

maggots from meat, and weevils from wheat. He observed the complete life cycle of ants, fleas, mussels, eels, and various insects, proving that all organisms have parents.

Fearfully and wonderfully made

Born into the Dutch Reformed tradition, which encouraged man's investigation of God's handiwork in nature, Leeuwenhoek shared with Robert Boyle and other "new philosophers" of science a concern to glorify God and benefit humankind through his research. He laced his writings with exclamations of the greatness and wisdom of the God who created the wonders he saw through his lenses. He marvelled at the perfection the Creator had built into even the tiniest, most hidden facets of Creation.

His stand against the myth of spontaneous generation was also a defense of the biblical doctrine of Creation against the incipient materialism that led Robert Boyle to establish his famous lectures (see "Newton vs. 'Newton,'" p. 30). The Dutch microscopist believed it foolish to think his "animalcules" could have formed by chance, and he worked diligently to prove that all things reproduce after their kind, as the book of Genesis teaches.

After working for weeks observing the propagation of insects, for example, Leeuwenhoek stated confidently, "This must appear wonderful, and be a confirmation of the principle that all living creatures deduce their origin from those which were formed at the Beginning."

Leeuwenhoek died in 1723, shortly after dictating a final set of observations to the Royal Society.

Microscopy has come a long way since then; scientists now use electron microscopes which, at 100,000x, are investigating wonders more amazing than Leeuwenhoek could have imagined: DNA, molecular motors, and the machinery of the cell.

With what captivated wonder—and what praises to God—would such discoveries be greeted by this untrained layman whose insatiable curiosity led him to open to science the frontier of the minuscule?

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CHRISTIAN HISTORY

Issue 76: The Christian Face of the Scientific Revolution

No Vein Inquiry

William Harvey founded modern physiology by seeking God's purposes for the body's design.

Emerson T. McMullen

William Harvey (1578-1657) founded the science of physiology by revolutionizing ideas on the movement of the heart and blood that had prevailed since Galen (ca. 130 - ca. 200). He not only discovered that the blood circulates and learned the true purpose of the venous valves and the heart's motion, but he also contributed to embryology and strongly influenced the next generation of medical researchers, setting the stage for modern medical science.

The London physician did this while acting as the resident doctor for the poor at St. Bartholomew's Hospital, a lecturer at the College of Physicians, a private practitioner, and later court physician to James I and personal physician to Charles I.

Harvey was influenced by the Calvinist environment of Cambridge (and indeed the Church of England) during his student years—his tutor at Cambridge, George Estey, was a clergyman and lecturer in Hebrew. Throughout his written works, Harvey reinterpreted the classical principle "Nature does nothing in vain" as a statement of God's sovereign purposefulness in creating and sustaining the natural world (reflected in Isaiah 45:18).

In his *Exercitationes de generatione animalium* (*Exercises on the Generation of Animals*, 1651), for example, he praised the workings of God's sovereignty in creation—which he termed "Nature." The theme is the book's *leitmotiv*: Nature "destines," "ordains," "intends," "gives gifts," "provides," "counter-balances," "institutes," and "is careful."

Harvey told a friend, "The examination of the bodies of animals has always been my delight; and I have thought that we might thence not only obtain an insight into the. ... mysteries of Nature, but there perceive a kind of image or reflex of the omnipotent Creator himself."

It was this keen sense of divine purpose that led Harvey to his momentous discovery of blood circulation. Having realized that the tiny valves in our veins allowed blood to flow only one way, Harvey struggled to determine God's purpose in their construction. As he considered the size of the arteries and the position and unidirectionality of the veins' valves, he concluded that the blood does not move back and forth in the veins and arteries, as once thought. Rather, it moves in a life-sustaining circuit, flowing out from the heart into the arteries and then returning through the veins. Echoing Leviticus 17:11 and 14, Harvey concluded, "life therefore resides in the blood (as we are informed in our sacred writings)."

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CHRISTIAN HISTORY

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The Christian Face of the Scientific Revolution: Christian History Interview - Natural Adversaries?

Historian David Lindberg shows that Christianity and science are not at war - and may never have been.

David Lindberg

Has Christianity always warred with science? Or, conversely, did Christianity create science? CH asked David Lindberg, Hilldale Professor Emeritus of the History of Science and currently director of the Institute for Research in the Humanities at the University of Wisconsin.

And he should know. Lindberg specializes in the history of medieval and early modern science, especially the interaction between science and religion. His *Beginnings of Western Science (University of Chicago Press, 1992)* is an oft-translated standard in the field. He is also currently the general editor, jointly with Ronald Numbers, of the forthcoming eight-volume Cambridge History of Science

Many people today have a sense that the church has always tried to quash science. Is this, indeed, the case?

This view is known as the "warfare thesis." It originated in the seventeenth century, but it came into its own with certain radical thinkers of the French Enlightenment. These people were eager to condemn the Catholic Church and went on the attack against it. So, for example, the Marquis de Condorcet (1743-1794), a mathematician and philosopher, assured his readers that Christianity's ascension during the Middle Ages resulted in "the complete decadence of philosophy and the sciences."

So how did this myth get from eighteenth-century France to twenty-first-century North America?

The men mostly responsible are John William Draper (1811-1882) and Andrew Dixon White (1832-1918). The more influential of the two was White, first president of Cornell University, who evoked strong opposition from religious critics for the secular curriculum (emphasizing the natural sciences) that he established at Cornell.

White responded with bitter attacks on his critics, culminating in his two-volume ***History of the Conflict Between Science and Religion*** (1874). White's book, still in print, continues to be powerfully influential.

What other myths about science and Christianity are commonly accepted today?

One obvious one maintains that before Columbus, Europeans believed nearly unanimously in a flat earth—a belief allegedly drawn from certain biblical statements and enforced by the medieval church.

This myth seems to have had an eighteenth-century origin, elaborated and popularized by Washington Irving, who flagrantly fabricated evidence for it in his four-volume history of Columbus. The myth was then picked up by White and others.

The truth is that it's almost impossible to find an educated person after Aristotle (d. 322 B.C.) who doubts that the earth is a sphere. In the Middle Ages, you couldn't emerge from any kind of education, cathedral school or university, without being perfectly clear about the earth's sphericity and even its approximate circumference.

Why does the myth live on?

Because it is a great illustration of other myths people fervently believe in, such as the barbaric ignorance of medieval people and the warfare thesis. You don't easily give up your best illustration of a deeply held belief.

Was there conflict between Christianity and science before the scientific revolution?

Christianity and science had a complex relationship.

Before Christ's birth, Aristotle and Plato had written treatises on scientific questions; some centuries later, Ptolemy and Galen would do the same. These books entered medieval Christendom during the twelfth century in Latin translation from Greek and Arabic versions. Christian scholars immediately realized that these books were incredibly impressive and valuable, teaching them how to think about a wide range of scientific questions.

But it was also clear that this body of writings (especially those by Aristotle) contained theological land-mines.

Aristotle believed in the eternity of the world.

He also judged the world to be deterministic, with no room for divine providence and divine action.

And Aristotle's philosophy was set within a rationalistic framework that maintained that true knowledge could be achieved only through observation and reason—thereby ruling out revelation as a source of truth.

Now one of the most durable myths about science and religion is that the church responded to these theologically dangerous teachings by suppressing Aristotle's writings and the rest of the ancient Greek scientific tradition.

What really happened?

Medieval scholars (university professors, including theology professors) were confronted by a terrible dilemma. They were not prepared to compromise the central doctrines of Christian theology. But they also recognized that the classical sciences had great explanatory power.

They preferred peace to warfare, so they looked for ways to accommodate this powerful tradition. They corrected the ancient sources where that seemed necessary, and on occasion they reinterpreted theological doctrines. And they argued vigorously for the usefulness of the classical sciences.

There were certainly skirmishes, including several cases in which a university scholar was condemned for teaching doctrines judged dangerous, but most of these were local and temporary. And there was never anything approaching intellectual warfare between theologians and scientists.

Roger Bacon, an outstanding scientist of the thirteenth century, is a good example of some of these developments. Borrowing a theme from St. Augustine, he argued that the classical scientific tradition could be the faithful handmaiden of theology and religion.

Thomas Aquinas and Albert the Great also contributed to this enterprise. They worked their way through Aristotle's writings line by line, looking for ways to reinterpret him or revise Christian theological doctrines to make them consistent with each other.

The point is that in the end, Christendom made its peace with the classical tradition. Aristotle's writings became the centerpiece of medieval university education, and the church became their

greatest patron.

What guided medieval scholars as they worked out this accommodation?

St. Augustine (354-430), the most influential theologian of the Middle Ages, gave them their principal tool. Augustine had cautioned that Christians should not make fools of themselves by reading their astronomy from the Bible. Don't embarrass the Christian faith with half-baked science.

Here's what Augustine wrote in his *Literal Commentary on Genesis*:

"Usually, even a non-Christian knows something about the earth, the heavens, and the other elements of this world, about the motion and orbit of the stars and even their size and relative positions, about the predictable eclipses of the sun and moon, the cycles of the years and the seasons, about the kinds of animals, shrubs, stones, and so forth, and this knowledge he holds as certain from reason and experience.

"Now it is a disgraceful and dangerous thing for an infidel to hear a Christian, presumably giving the meaning of Holy Scripture, talking nonsense on these topics; and we should take all means to prevent such an embarrassing situation, in which people reveal vast ignorance in a Christian and laugh that ignorance to scorn."

The result of Bacon's work, and Aquinas's, and Albert's, and that of many others less well known, was a Christianized Aristotle and an Aristotelianized Christianity.

And does this Christianization affect or limit science in any way?

It depends on the area. In technical areas—the mathematical sciences, medicine, and other "non-worldview" sciences—not in the least. For example, in the history of geometrical optics (a favorite study of medieval scholars and one of my own historical specialties), I have yet to find a single theoretical claim that is in any way altered by the Christian context in which that research took place.

Did Christianization ever motivate scientific investigation?

Definitely. For example, Roger Bacon argued that if you wanted to interpret scriptural passages that touch on the heavens or other objects of scientific investigation, you had to have scientific knowledge. And quite a large amount of scientific content is found in medieval theological treatises.

Given everything you've said, what can we conclude about the causes of the scientific revolution?

There are two widely-held theories, both involving religion. One maintains that the scientific revolution was the product of European secularization, as Christianity lost its hold on educated Europeans. The other claims that the scientific revolution was a product of religious reform—specifically, the Protestant Reformation.

In my opinion, neither of these positions is defensible. Many factors contributed to the scientific revolution, but it was most fundamentally a continuation and outgrowth of medieval institutions (the universities) and of the Christianized classical scientific tradition of the Middle Ages.

So neither Protestants nor Catholics invented modern science. Their theology or worldview was not the ground or source from which modern science emerged; but they did provide a context within which the natural sciences developed and flourished.

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The Christian Face of the Scientific Revolution: Recommended Resources

Chris Armstrong

The field of science and religion has experienced something of an academic boom in recent years—no doubt due in part to funding organizations such as the John Templeton Foundation. Most of the following resources go beyond the scientific revolution, but all have substantial material on that era.

Books

An accessible entree to questions about Biblical interpretation and the scientific revolution is Charles Hummel, *The Galileo Connection* (IVP, 1986). The book contains neatly interwoven mini-biographies of Copernicus, Galileo, Kepler, Newton, and Pascal, along with chapters on biblical interpretation and on flashpoints of modern science-faith conflict.

One of the best academic introductions to this area is still David Lindberg and Ronald Numbers, ed., *God and Nature: Historical Essays on the Encounter Between Christianity and Science* (University of California Press, 1986). Its fascinating essays are concise treatments of the relationship between Christianity and science in different periods and groups.

For readers looking for a synthesis of the issues at stake in this relationship, a good tour guide is Ian Barbour. Start with his *Religion and Science: Historical and Contemporary Issues* (HarperCollins, 1997), a significantly expanded version of the standard text, *Religion in an Age of Science*.

One of the most penetrating and readable authorities is John Hedley Brooke. See especially his *Science and Religion: Some Historical Perspectives* (Cambridge University Press, 1991) and his *Reconstructing Nature: The Engagement of Science and Religion* (Oxford University Press, 2000). The latter is an updating, with Geoffrey Cantor, of the author's Gifford Lectures. It traces the relationship of Christianity and science through history, busts myths, and contains a chapter on the modern relevance of the Galileo Affair.

David N. Livingstone, D. G. Hart, and Mark A. Noll have edited a volume on *Evangelicals and Science in Historical Perspective, Religion in America Series* (Oxford University Press, 2002). This contains a chapter by Brooke, "*The History of Science and Religion: Some Evangelical Dimensions.*"

For a meticulously researched account of a single important issue, see Kenneth J. Howell, *God's Two Books: Copernican Cosmology and Biblical Interpretation in Early Modern Science* (University of Notre Dame, 2002).

Two fascinating reads are Dava Sobel's *Galileo's Daughter* (Penguin USA, 2000) and J. L. Heilbron, *The Sun in the Church: Cathedrals as Solar Observatories* (Harvard University Press, 1999), which tells how the Catholic church supported astronomical research through the design of four cathedrals built between 1650 and 1750.

Websites

The internet provides an abundance of materials on this topic, including much of high quality.

The Counterbalance Foundation provides a great introduction to the basic issues, historical, theological, and philosophical, at <http://www.meta-library.net/>. The site provides what amounts to an entire online course on the subject of science-faith interactions, complete with video clips of lectures and recommendations for further reading. Its wellwritten capsules feature the thought of several of the authors mentioned above and throughout this issue, among other respected experts.

An outstanding research tool is Richard S. Westfall's database, the "Catalog of the Scientific Community in the 16th and 17th centuries." The database contains 631 detailed, point-form biographies searchable on 20 fields, including-take note!-a field containing analyses, sometimes quite detailed, of the religious preferences of each scientist. This gem may be found at <http://es.rice.edu/ES/humsoc/Galileo/Catalog/catalog.html>.

For a gateway to a variety of intellectually challenging (and theologically broad) online journals, organizations, and websites on science and faith, see the page of science and religion links at the John Templeton society website: <http://www.templeton.org/links.asp#science>.

A beguiling and visually rich browse through Galileo's life, thought, and times is Rice University's "Galileo Project" site, at <http://es.rice.edu/ES/humsoc/Galileo/>.

—*Chris Armstrong*

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