On the Revolutions of the Heavenly Spheres

Nicolaus Copernicus began a revolution in astronomy when he argued that the sun and not the earth was at the center of the universe. Expecting controversy and scorn, Copernicus hesitated to publish the work in which he put forth his heliocentric theory. He finally relented, however, and managed to see a copy of it just before he died.

Nicolaus Copernicus, *On the Revolutions of the Heavenly Spheres*

For a long time, then, I reflected on this confusion in the astronomical traditions concerning the derivation of the motions of the universe's spheres. I began to be annoyed that the movements of the world machine, created for our sake by the best and most systematic Artisan of all [God], were not understood with greater certainty by the philosophers, who otherwise examined so precisely the most insignificant trifles of this world. For this reason I undertook the task of rereading the works of all the philosophers which I could obtain to learn whether anyone had ever proposed other motions of the universe's spheres than those expounded by the teachers of astronomy in the schools. And in fact first I found in Cicero that Hicetas supposed the earth to move. Later I also discovered in Plutarch that certain others were of this opinion. I have decided to set his words down here, so that they may be available to everybody:

> Some think that the earth remains at rest. But Philolaus the Pythagorean believes that, like the sun and moon, it revolves around the fire in an oblique circle. Heraclides of Pontus and Ecphantus the Pythagorean make the earth move, not in a progressive motion, but like a wheel in a rotation from the west to east about its own center.

Therefore, having obtained the opportunity from these sources, I too began to consider the mobility of the earth. And even though the idea seemed absurd, nevertheless I knew that others before me had been granted the freedom to imagine any circles whatever for the purpose of explaining the heavenly phenomena. Hence I thought that I too would be readily permitted to ascertain whether explanations sounder than those of my predecessors could be found for the revolution of the celestial spheres on the assumption of some motion of the earth.

Having thus assumed the motions which I ascribe to the earth later on in the volume, by long and intense study I finally found that if the motions of the other planets are correlated with the orbiting of the earth, and are computed for the revolution of each planet, not only do their phenomena follow therefrom but also the order and size of all the planets and spheres, and heaven itself is so linked together that in no portion of it can anything be shifted without disrupting the remaining parts and the universe as a whole . . .

Hence I feel no shame in asserting that this whole region engirdled by the moon, and the center of the earth, traverse this grand circle amid the rest of the planets in an annual revolution around the sun. Near the sun is the center of the universe. Moreover, since the sun remains stationary, whatever appears as a motion of the sun is really due rather to the motion of the earth.

Q **HISTORICAL THINKING SKILL: Patterns of Continuity and Change over Time** *How was Copernicus's first step in his inquiry into planetary motion typical of Renaissance thinking?*

Source: From *The Collected Works* by Copernicus, translated by Edward Rosen. Rev. ed. published 1978 by Palgrave Macmillan. Reproduced with permission of Palgrave Macmillan.

with the observed motions of the heavenly bodies (see the box above). Copernicus hoped that his **heliocentric** or sun-centered conception would offer a simpler and more accurate explanation.

Copernicus argued that the universe consisted of eight spheres with the sun motionless at the center and the sphere of the fixed stars at rest in the eighth sphere. The planets revolved around the sun in the order of Mercury, Venus, the earth, Mars, Jupiter, and Saturn. The moon, however, revolved around the earth. Moreover, according to Copernicus, what appeared to be the movement of the sun and the fixed stars around the earth was really explained by the daily rotation of the earth on its axis and the journey of the earth around the sun each year.

Copernicus, however, was basically conservative. He did not reject Aristotle's principle of the existence of heavenly spheres moving in circular orbits. As a result, when he put forth the calculations to prove his new theory, he retained about half of Ptolemy's epicycles and wound up with a system somewhat simpler than that of the Alexandrian astronomer but still extremely complicated.

Nevertheless, the shift from an earth-centered to a sun-centered system was significant and raised serious questions about Aristotle's astronomy and physics despite Copernicus's own adherence to Aristotle. It also seemed to create uncertainty about the human role in the universe as well as God's location. Protestant reformers, adhering to a literal interpretation of Scripture, were the first to attack the new ideas. Martin Luther thundered against "the new astrologer who wants to prove that the earth moves and goes round. . . . The fool wants to turn the whole art of astronomy upside down. As Holy Scripture tells us, so did Joshua bid the sun stand still

Kepler and the Emerging Scientific Community

THE EXCHANGE OF LETTERS BETWEEN INTELLECTUALS was an important avenue for scientific communication. After receiving a copy of Johannes Kepler's first major work, the Italian Galileo Galilei wrote to Kepler, inaugurating a correspondence between them. This selection contains samples of their letters to each other.

Galileo to Kepler, Padua, August 4, 1597

Your book, highly learned gentleman, which you sent me through Paulus Amberger, reached me not days ago but only a few hours ago, and as this Paulus just informed me of his return to Germany, I should think myself indeed ungrateful if I should not express to you my thanks by this letter. I thank you especially for having deemed me worthy of such a proof of your friendship. . . . So far I have read only the introduction, but have learned from it in some measure your intentions and congratulate myself on the good fortune of having found such a man as a companion in the exploration of truth. For it is deplorable that there are so few who seek the truth and do not pursue a wrong method of philosophizing. But this is not the place to mourn about the misery of our century but to rejoice with you about such beautiful ideas proving the truth. . . . I would certainly dare to approach the public with my ways of thinking if there were more people of your mind. As this is not the case, I shall refrain from doing so. . . . I shall always be at your service. Farewell, and do not neglect to give me further good news of yourself.

Yours in sincere friendship,
Galilaeus Galilaeus
Mathematician at the Academy of Padua

Kepler to Galileo, Graz, October 13, 1597

I received your letter of August 4 on September 1. It was a double pleasure to me. First because I became friends with you, the Italian, and second because of the agreement in which we find ourselves concerning Copernican cosmography. As you invite me kindly at the end of your letter to enter into correspondence with you, and I myself feel greatly tempted to do so, I will not let pass the occasion of sending you a letter with the present young nobleman. For I am sure, if your time has allowed it, you have meanwhile obtained a closer knowledge of my book. And so a great desire has taken hold of me, to learn your judgment. For this is my way, to urge all those to whom I have written to express their candid opinion. Believe me, the sharpest criticism of one single understanding man means much more to me than the thoughtless applause of the great masses.

I would, however, have wished that you who have such a keen insight into everything would choose another way to reach your practical aims. By the strength of your personal example you advise us, in a cleverly veiled manner, to go out of the way of general ignorance and warn us against exposing ourselves to the furious attacks of the scholarly crowd. . . . But after the beginning of a tremendous enterprise has been made in our time, and furthered by so many learned mathematicians, and after the statement that the earth moves can no longer be regarded as something new, would it not be better to pull the rolling wagon to its destination with united effort? . . . For it is not only you Italians who do not believe that they move unless they feel it, but we in Germany, too, in no way make ourselves popular with this idea. Yet there are ways in which we protect ourselves against these difficulties. . . . Be of good cheer, Galileo, and appear in public. If I am not mistaken there are only a few among the distinguished mathematicians of Europe who would dissociate themselves from us. So great is the power of truth. If Italy seems less suitable for your publication and if you have to expect difficulties there, perhaps Germany will offer us more freedom. But enough of this. Please let me know, at least privately if you do not want to do so publicly, what you have discovered in favor of Copernicus.

HISTORICAL THINKING SKILL: Contextualization
What would have made Galileo uneasy about associating himself with Copernicus's ideas? How was Kepler's situation different?

Source: From *Johannes Kepler, Life and Letters* by Carola Baumgardt, copyright 1951 by the Philosophical Library. Used by permission.

and unchanging. Published ten years later, Kepler's third law established that the square of a planet's period of revolution is proportional to the cube of its average distance from the sun. In other words, planets with larger orbits revolve at a slower average velocity than those with smaller orbits.

Kepler's three laws effectively eliminated the idea of uniform circular motion as well as the idea of crystalline spheres revolving in circular orbits. The basic structure of the traditional Ptolemaic system had been disproved, and people had been freed to think in new ways about the actual paths of planets revolving around the sun in elliptical orbits. By the end of Kepler's life, the Ptolemaic system was rapidly losing ground to the new ideas (see the box above). Important questions remained unanswered, however: What were the planets made of? And how could motion in the universe be explained? It was an Italian scientist who achieved the next important breakthrough to a new cosmology by answering the first question and making important strides toward answering the second.

The Starry Messenger

THE ITALIAN GALILEO GALILEI WAS THE FIRST European to use a telescope to make systematic observations of the heavens. His observations, as reported in *The Starry Messenger* in 1610, stunned European intellectuals by revealing that the celestial bodies were not perfect and immutable but composed of material substance similar to that of the earth. In this selection, Galileo describes how he devised a telescope and what he saw with it.

Galileo Galilei, *The Starry Messenger*

About ten months ago a report reached my ears that a certain Fleming had constructed a spyglass by means of which visible objects, though very distant from the eye of the observer, were distinctly seen as if nearby. Of this truly remarkable effect several experiences were related, to which some persons gave credence while others denied them. A few days later the report was confirmed to me in a letter from a noble Frenchman at Paris, Jacques Badovere, which caused me to apply myself wholeheartedly to inquire into the means by which I might arrive at the invention of a similar instrument. This I did shortly afterwards, my basis being the theory of refraction. First I prepared a tube of lead, at the ends of which I fitted two glass lenses, both plane on one side while on the other side one was spherically convex and the other concave. Then placing my eye near the concave lens I perceived objects satisfactorily large and near, for they appeared three times closer and nine times larger than when seen with the naked eye alone. Next I constructed another one, more accurate, which represented objects as enlarged more than sixty times. Finally, sparing neither labor nor expense, I succeeded in constructing for myself so excellent an instrument that objects seen by means of it appeared nearly one thousand times larger and over thirty times closer than when regarded without natural vision.

It would be superfluous to enumerate the number and importance of the advantages of such an instrument at sea as well as on land. But forsaking terrestrial observations, I turned to celestial ones, and first I saw the moon from as near at hand as if it were scarcely two terrestrial radii. After that I observed often with wondering delight both the planets and the fixed stars, and since I saw these latter to be very crowded, I began to seek (and eventually found) a method by which I might measure their distances apart. . . .

Now let us review the observations made during the past two months, once more inviting the attention of all who are eager for true philosophy to the first steps of such important contemplations. Let us speak first of that surface of the moon which faces us. For greater clarity I distinguish two parts of this surface, a lighter and a darker; the lighter part seems to surround and to pervade the whole hemisphere, while the darker part discolors the moon's surface like a kind of cloud, and makes it appear covered with spots. . . . From observation of these spots repeated many times I have been led to the opinion and conviction that the surface of the moon is not smooth, uniform, and precisely spherical as a great number of philosophers believe it (and the other heavenly bodies) to be, but is uneven, rough, and full of cavities and prominences, being not unlike the face of the earth, relieved by chains of mountains and deep valleys.

Q **HISTORICAL THINKING SKILL: Patterns of Continuity and Change over Time** *What was new, significant, and possibly dangerous to himself about Galileo's observations and conclusions?*

system because it threatened not only Scripture but also an entire conception of the universe (see the box on p. 485). The heavens were no longer a spiritual world but a world of matter. Humans were no longer at the center, and God was no longer in a specific place. The new system raised such uncertainties that it seemed prudent simply to condemn it.

Galileo, however, never really accepted his condemnation. In 1632, he published his most famous work, *Dialogue on the Two Chief World Systems: Ptolemaic and Copernican*. Unlike most scholarly treatises, it was written in Italian rather than Latin, making it more widely available to the public, which no doubt alarmed the church authorities. The work took the form of a dialogue among Simplicio, a congenial but somewhat stupid supporter of Aristotle and Ptolemy; Sagredo, an open-minded layman; and Salviati, a proponent of Copernicus's ideas. There is no question who wins the argument, and the *Dialogue* was quickly perceived as a defense of the Copernican system. Galileo was dragged once more before the Inquisition in 1633, found guilty of teaching the condemned Copernican system, and forced to recant his errors. Placed under house arrest on his estate near Florence, he spent the remaining eight years of his life studying mechanics, a field in which he made significant contributions.

GALILEO AND THE PROBLEM OF MOTION One of the problems that fell under the heading of mechanics was the principle of motion. The Aristotelian conception, which dominated the late medieval world, held that an object remained at rest unless a force was applied against it. If a force was constantly exerted, then the object moved at a constant rate, but if it was removed, then the object stopped. This conception encountered some difficulties, especially with a projectile thrown out of a cannon. Late medieval theorists had solved this problem by arguing that the rush of air behind the projectile kept it in motion. The Aristotelian principle of motion also raised problems in the new

OPPOSING ✂ VIEWPOINTS

A New Heaven? Faith Versus Reason

In 1614, Galileo wrote a letter to the Grand Duchess Christina of Tuscany in which he explained why his theory that the earth rotated around the sun was not necessarily contrary to Scripture. To Galileo, it made little sense for the church to determine the nature of physical reality on the basis of biblical texts that were subject to different interpretations. One year later, Cardinal Robert Bellarmine, a Jesuit and now a member of the church's Inquisition, wrote a letter to one of Galileo's followers that laid out the Catholic Church's approach to the issue of Galileo's theory.

Galileo, Letter to the Grand Duchess Christina, 1614

Some years ago, as Your Serene Highness well knows, I discovered in the heavens many things that had not been seen before our own age. The novelty of these things, as well as some consequences which followed from them in contradiction to the physical notions commonly held among academic philosophers, stirred up against me no small number of professors—as if I had placed these things in the sky with my own hands in order to upset nature and overturn the sciences. . . .

Contrary to the sense of the Bible and the intention of the holy Fathers, if I am not mistaken, they would extend such authorities until even in purely physical matters—where faith is not involved—they would have us altogether abandon reason and the evidence of our senses in favor of some biblical passage, though under the surface meaning of its words this passage may contain a different sense. . . .

The reason produced for condemning the opinion that the earth moves and the sun stands still is that in many places in the Bible one may read that the sun moves and the earth stands still. Since the Bible cannot err, it follows as a necessary consequence that anyone takes an erroneous and heretical position who maintains that the sun is inherently motionless and the earth movable.

With regard to this argument, I think in the first place that it is very pious to say and prudent to affirm that the holy Bible can never speak untruth—whenever its true meaning is understood. But I believe nobody will deny that it is often very abstruse, and may say things which are quite different from what its bare words signify. Hence, in expounding the Bible if one were always to confine oneself to the unadorned grammatical meaning, one might fall into error. Not only contradictions and propositions far from true might thus be made to appear in the Bible, but even grave heresies and follies. Thus, it would be necessary to assign to God feet, hands, and eyes, as well as corporeal and human affections, such as anger, repentance, hatred, and sometimes even the forgetting of things past and ignorance of those to come. These propositions uttered by the Holy Ghost were set down in that manner by the sacred scribes in order to accommodate them to the capacities of the common people, who are rude and unlearned. For the sake of those who deserve to be separated from the herd, it is necessary that wise expositors should produce the true senses of such passages, together with the special reasons for which they were set down in these words. . . .

This being granted, I think that in discussions of physical problems we ought to begin not from the authority of scriptural passages, but from sense-experiences and necessary demonstrations; for the holy Bible and the phenomena of nature proceed alike from the divine Word. . . . For that reason it appears that nothing physical which sense-experience sets before our eyes, or which necessary demonstrations prove to us, ought to be called in question (much less condemned) upon the testimony of biblical passages which may have some different meaning beneath their words.

Robert Bellarmine, Letter to Paolo Foscarini, 1615

First. I say that it seems to me that Your Reverence and Galileo did prudently to content yourself with speaking hypothetically, and not absolutely, as I have always believed that Copernicus spoke. For to say that, assuming the earth moves and the sun stands still, all the appearances are saved better than with eccentrics and epicycles, is to speak well; there is no danger in this, and it is sufficient for mathematicians. But to want to affirm that the sun really is fixed in the center of the heavens and only revolves around itself (i.e., turns upon its axis) without traveling from east to west, and that the earth is situated in the third sphere and revolves with great speed around the sun, is a very dangerous thing, not only by irritating all the philosophers and scholastic theologians, but also by injuring our holy faith and rendering the Holy Scriptures false. For Your Reverence has demonstrated many ways of explaining Holy Scripture, but you have not applied them in particular, and without a doubt you would have found it most difficult if you had attempted to explain all the passages which you yourself have cited.

Second. I say that, as you know, the Council [of Trent] prohibits expounding the Scriptures contrary to the common agreement of the holy Fathers. And if Your Reverence would read not only the Fathers but also the commentaries of modern writers on Genesis, Psalms, Ecclesiastes and Josue, you would find that all agree in explaining literally (*ad litteram*) that the sun is in the heavens and moves swiftly around the earth, and that the earth is far from the heavens and stands immobile in the center of the universe. Now consider whether in all prudence the Church could encourage giving to Scripture a sense contrary to the holy Fathers and all the Latin and Greek commentators. Nor may it be answered that this is not a matter of faith, for if it is not a matter of faith from the point of view of the subject matter, it is on the part of the ones who have spoken. . . .

(continued)

(Opposing Viewpoints continued)

Third. I say that if there were a true demonstration that the sun was in the center of the universe and the earth in the third sphere, and that the sun did not travel around the earth but the earth circled the sun, then it would be necessary to proceed with great caution in explaining the passages of Scripture which seemed contrary, and we would rather have to say that we did not understand them than to say that something was false which has been demonstrated. But I do not believe that there is any such demonstration; none has been shown to me. It is not the same thing to show that the appearances are saved by assuming that the sun really is in the center and the earth in the heavens. I believe that the first demonstration might exist, but I have grave doubts about the second, and in a case of doubt, one may not depart from the Scriptures as explained by the holy Fathers.

HISTORICAL THINKING SKILL: Historical Causation
Why did Galileo's defense of learning through observation lead to attacks from the Inquisition?

Source: Galileo, Letter to the Grand Duchess Christina, 1614, From DISCOVERIES AND OPINIONS OF GALILEO by Galileo Galilei, translated by Stillman Drake, copyright © 1957 by Stillman Drake. Used by permission of Doubleday, a division of Random House, Inc. Robert Bellarmine, Letter to Paolo Foscarini, 1615. From Galileo, Science, and the Church by Jerome J. Langford (New York: Desclee, 1966).

Copernican system. In the Ptolemaic system, the concentric spheres surrounding the earth were weightless, but in the Copernican system, if a constant force had to be applied to objects to cause movement, then what power or force kept the heavy earth and other planets in motion?

Galileo made two contributions to the problem of motion. First, he demonstrated by experiments that if a uniform force was applied to an object, it would move at an accelerated speed rather than a constant speed. Moreover, Galileo discovered the principle of inertia when he argued that a body in motion continues in motion forever unless deflected by an external force. Thus, a state of uniform motion is just as natural as a state of rest. Before Galileo, natural philosophers had tried to explain motion; now their task was to explain changes in motion.

The condemnation of Galileo by the Inquisition, coming at a time of economic decline, seriously undermined further scientific work in Italy, which had been at the forefront of scientific innovation. Leadership in science now passed to the northern countries, especially England, France, and the Dutch Netherlands. By the 1630s and 1640s, no reasonable astronomer could overlook that Galileo's discoveries, combined with Kepler's mathematical laws, had made nonsense of the Aristotelian-Ptolemaic world system and clearly established the reasonableness of the Copernican model. Nevertheless, the problem of explaining motion in the universe and tying together the ideas of Copernicus, Galileo, and Kepler had not yet been solved. This would be the work of an Englishman who has long been considered the greatest genius of the Scientific Revolution.

Newton

Born in the English village of Woolsthorpe in 1642, Isaac Newton was an unremarkable young man until he attended Cambridge University. His first great burst of creative energy came in 1666, when fear of the plague closed Cambridge and forced him to return to Woolsthorpe for eighteen months. There Newton discovered his creative talents: "In those days I was in the prime of my life for invention and minded mathematics and philosophy more than at any time since."[9] During this period, he invented the calculus, a mathematical means of calculating rates of change; began his investigations into the composition of light; and inaugurated his work on the law of universal gravitation. Two years after his return to Cambridge, in 1669, he accepted a chair in mathematics at the university. During a second intense period of creativity from 1684 to 1686, he wrote his famous *Principia* (prin-SIP-ee-uh) (see the box on p. 487). After a nervous breakdown in 1693, he sought and received an administrative post as warden of the royal mint and was advanced to master of the mint by 1699, a post he held until his death in 1727. Made president of the Royal Society (see "The Scientific Societies" later in this chapter) in 1703 and knighted in 1705 for his great achievements, Sir Isaac Newton is to this day the only English scientist to be buried in Westminster Abbey.

NEWTON AND THE OCCULT Although Newton occupies a very special place in the history of modern science, we need to remember that he, too, remained extremely interested in aspects of the occult world. He left behind hundreds of manuscript pages of his studies of alchemy, and in fact, his alchemical experiments were a major feature of his life until he moved to London in 1696 to become warden of the royal mint. The British economist John Maynard Keynes said of Newton after examining his manuscripts in 1936:

> Newton was not the first of the age of reason. He was the last of the magicians. . . . He looked on the whole universe and all that is in it as a riddle, as a secret which could be read by applying pure thought to certain evidence, certain mystic clues which God had laid about the world to allow a sort of philosopher's treasure hunt to the esoteric brotherhood. He believed that these clues were to be found partly in the evidence of the heavens and in the constitution of elements, . . . but also partly in certain papers and traditions handed down by the brethren in an unknown chain back to the original cryptic revelation in Babylonia.[10]

Newton's Rules of Reasoning

IN 1687, ISAAC NEWTON PUBLISHED HIS MASTERPIECE, the *Mathematical Principles of Natural Philosophy*, or *Principia*. In this work, Newton demonstrated the mathematical proofs for his universal law of gravitation and completed the new cosmology begun by Copernicus, Kepler, and Galileo. He also described the rules of reasoning by which he arrived at his universal law.

Isaac Newton, *Rules of Reasoning in Philosophy*

Rule 1

We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.

To this purpose the philosophers say that Nature does nothing in vain, and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes.

Rule 2

Therefore to the same natural effects we must, as far as possible, assign the same causes.

As to respiration in a man and in a beast; the descent of stones in Europe and in America; the light of our culinary fire and of the sun; the reflection of light in the earth and in the planets.

Rule 3

The qualities of bodies, which admit neither intensification nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.

For since qualities of bodies are only known to us by experiments, we are to hold for universal all such as universally agree with experiments; and such as are not liable to diminution can never be quite taken away.

Rule 4

In experimental philosophy we are to look upon propositions inferred by general induction from phenomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phenomena occur, by which they may either be made more accurate, or liable to exceptions.

This rule we must follow, that the argument of induction may not be evaded by hypotheses.

Q **HISTORICAL THINKING SKILL: Contextualization**
How might following Newton's rules of reasoning have changed future scientific inquiry?

Source: From Isaac Newton, *The Mathematical Principles of Natural Philosophy*, 2 volumes (London, 1803), vol. 2: pp. 160–62.

Although Newton may have considered himself a representative of the Hermetic tradition, he chose, it has been recently argued, for both political and psychological reasons to repress that part of his being, and it is as the "symbol of Western science" that he came to be viewed.

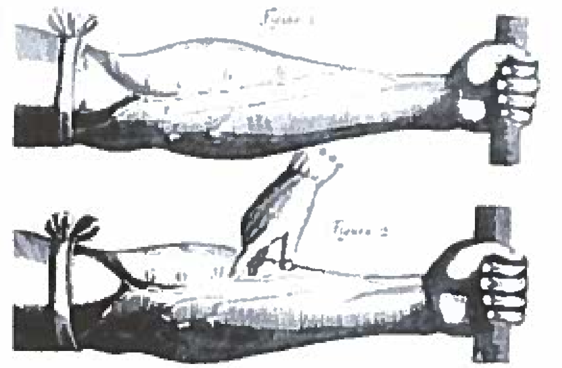
UNIVERSAL LAW OF GRAVITATION Newton's major work, the "hinge point of modern scientific thought," was his *Mathematical Principles of Natural Philosophy*, known simply as the *Principia*, the first word of its Latin title. In this work, the last highly influential book in Europe to be written in Latin, Newton spelled out the mathematical proofs demonstrating his universal law of gravitation. Newton's work was the culmination of the theories of Copernicus, Kepler, and Galileo. Though each had undermined some part of the Aristotelian-Ptolemaic cosmology, until Newton no one had pieced together a coherent synthesis for a new cosmology.

National Portrait Gallery, London/The Bridgeman Art Library

Isaac Newton. With a single law, that of universal gravitation, Isaac Newton was able to explain all motion in the universe. His great synthesis of the work of his predecessors created a new picture of the universe, one in which the universe was viewed as a great machine operating according to natural laws. Enoch Seeman painted this portrait of Newton one year before his death.

William Harvey (1578-1657)

Until the early 17th century Claudius Galen's books were still being used in some medical schools. Although Andreas Vesalius had proved some of his ideas to be incorrect, Galen's explanation of the heart was still preferred by most doctors. It was William Harvey who proved that Galen was wrong and so made one of the most famous of medical discoveries.



Sketch of valves on the arms from Harvey's book

Who was William Harvey?

Harvey was a doctor at St. Bartholomew's hospital in London and a Fellow of the Royal College of Physicians. He was also the physician to James I and Charles I. Harvey studied in Italy at the University of Padua where he became interested in anatomy and in particular, the work of Vesalius.

What were his important discoveries?

In 1615 Harvey began to work on the idea that blood circulated around the body. By experimenting on live animals and dissecting the bodies of executed criminals, Harvey was able to prove that the heart was a pump which forced blood around the body through arteries. Veins then returned the blood to the heart where it was recycled. Harvey's work was helped by the discovery that veins contained valves. Harvey realized that these valves stopped the blood from traveling back the wrong way to the heart. Galen's theory (that the body made new blood as its supplies were used up) was proved wrong. In 1628, Harvey published details of his work in his book entitled 'An Anatomical Disquisition on the Movement of the Heart and Blood.'

Why did Harvey face opposition?

After his work was published, Harvey actually lost patients, as his ideas were considered eccentric. It was not until after his death that others became convinced that he was right. Marcello Malpighi (1628-1694), an Italian physician, used better quality microscopes to prove that Harvey's ideas were correct.

How important was Harvey?

Harvey's work made little difference to general medical practice at the time. Blood letting continued to be a popular practice and it was not until the 20th century that doctors realized the importance of checking a patient's blood flow by taking a pulse. Harvey's work did encourage others to investigate blood circulation, e.g. the blood's role in carrying air from the lungs. His discovery of blood circulation was central to a proper understanding of the workings of the body.

Questions

1. **Who was William Harvey and where did he study?**
2. **What did Harvey discover?**
3. **Why weren't Harvey's ideas accepted by many people at the time?**
4. **What was the long term importance of Harvey's work?**