

AP European History - Chapter 16 *The Scientific Revolution* Class Notes & Critical Thinking

Focus Question: What developments during the Middle Ages and the Renaissance contributed to the Scientific Revolution of the seventeenth century?

Science Becomes More “Modern”:

- Science: ↑ of civilization & progress
- Applied to all aspects of society
- Man: power to reason – develop ideas, solve problems
- Affects practical affairs: health, wealth, raw materials use, prod., transp., business, war, etc
- Aggravates some
- Science changed religion, God, man, & ideals of physical universe & belief in free & democratic ideals
- Knowledge replaces superstition
- Secularizes society-church loses more power
- Man believes he can run the universe



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Profits of Scientific Civilization:

- Leonardo da Vinci
 - Artist, engineer, never wrote down any scientific thoughts so not known as Scientist but had sketches
- Skepticism:
 - Constant doubting of the mind, no certain knowledge is possible of humans
 - Some believe 1 thing, others another
 - Montaigne
- Tendency to Over-Believe
 - Inability to distinguish b/n true & false
 - Things alike according to secrets of nature: chemistry & alchemy – astronomy & astrology

Profits of Scientific Civilization:

- Charlatans
 - 1 that pretends knowledge: mixes science & magic
 - **Nostradamus:** belief in magic
 - Predicted events – saw future by stars
 - Forerunner of scientific revolution
 - Paracelsus: Alchemist-helped chemistry
 - Theories used today
 - Helped medicine
- Witchcraft
 - Didn't fit into scientific method
 - Tendency to over belief
 - 100's killed in 1450's-1650's
 - Ended when Europe was more stable



Critical Thinking:

Of the factors that contributed to the Scientific Revolution, which one do you think had the most impact & why?

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Focus Question: What did Copernicus, Kepler, Galileo, and Newton contribute to a new vision of the universe, and how did it differ from the Ptolemaic conception of the universe?

Scientific Advancements

- *Ptolemy*: Egyptian; Other spheres revolved around earth
- *Aristotle*: Earth center of universe

Nicholas Copernicus (1473-1543)

- Book: On the Revolution of the Heavenly Spheres
- Sun center solar system & fixed stars & others revolve around it (church opposed)
- To him: mathematical problem
- Not accepted at 1st

Johannes Kepler (1571-1630)

- *New Astronomy or Celestial Physics*
- Mathematician, astrologer, scientific genius
- Accepted Copernicus
- Kepler's 3 Laws:
 - Orbits of planets around sun = ellipse
 - Line drawn b/n planet & sun sweeps = time squared = distance cubed
 - Closer to sun = faster planet moves
- Relationship b/n space & time

Galileo Galilei (1564-1642)

- Founded experimental science
- 1st science of modern thought
- Built telescope & tried to prove:
 - Facts of moon
 - Spots on sun not perfect
 - Planets had size but stars pts of light
 - Jupiter had moons
 - Difference b/n earth & heavens
 - Condemned – told to recant
 - Dropped 2 balls at same speed = Law of Pendulum & Falling Bodies
- Found guilty of heresy by Cath. Church

Sir Isaac Newton (1642-1727)

- Kepler's & Galileo's Laws the same law – 2 parts
- Law of Universal Gravitation=gravity
- Showed why planets move elliptical – pulled toward sun
- Laws produced exact math knowledge of solar system
- Great help to navigation & map making
- World Machine:
 - Used Newton's rules of reasoning & found natural laws governed politics, economics, justice, religion, arts

Critical Thinking:

Draw a diagram demonstrating the progression of theories during the Scientific Revolution.

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 Ephantus 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,



What major new ideas did Copernicus discuss in this excerpt? What was the source of these ideas? Why might one say that European astronomers had finally destroyed the Middle Ages?

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

1. What major new ideas did Copernicus discuss in this excerpt? What was the source of these ideas?
2. Why might one say that European astronomers had finally destroyed the Middle Ages?
3. PATTERNS OF CONTINUITY AND CHANGE: How was Copernicus's first step in his inquiry into planetary motion typical of Renaissance thinking?

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Make a T-Chart showing the differences between the scientific ideas of the seventeenth century and those of ancient times.

Seventeenth Century	Ancient Times

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)

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(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.



What does Galileo think is the difference between knowledge about the natural world and knowledge about the spiritual world? What does Galileo suggest that his opponents should do before dismissing his ideas? In what ways does Cardinal Bellarmine attempt to refute Galileo's ideas? Why did Galileo's ideas represent a threat to the Catholic Church?

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: Desclée, 1966).

1. What does Galileo think is the difference between knowledge about the natural world and knowledge about the spiritual world?
2. What does Galileo suggest that his opponents should do before dismissing his ideas?
3. CAUSATION: Why did Galileo's defense of learning through observation lead to attacks from the Inquisition?

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Focus Question: What did Paracelsus, Vesalius, and Harvey contribute to a scientific view of medicine?

Galen

- Greek physician Ancient view of anatomy
- 2 separate blood systems
- 4 humors:
 - blood: warm & moist
 - yellow bile: warm & dry
 - phlegm: cold & moist
 - black bile: cold & dry
- Animal dissection led to major errors understanding human anatomy

Paracelsus

- Truly believed in the healing power of natural treatments and recourses
- Only through a harmonic and balanced interrelation between man (microcosm) and nature (macrocosm) could health be obtained:
 - “Man is a microcosm, or a little world, because he is an extract from all the stars and planets of the whole firmament, from the earth and the elements; and so he is their quintessence.”
- Only through an understanding of the principles of the universe could the body be understood.
- Rejected discoveries of the human anatomy - one must study nature in order to understand the human body = astrology important role

Andreas Vesalius (1514-1564)

- Renaissance physician who revolutionized the study of biology & practice of medicine by his careful description of the anatomy of the human body.
- Based observations on dissections he made himself = much opposition to it
- Wrote & illustrated the first comprehensive textbook of anatomy
 - *On the Fabric of the Human Body*

William Harvey (1578-1657)

- Known for discovery of circulation of blood & role of heart in the body
 - Blood originates in heart & travels through arteries & veins
 - Contradicted Galen's theories of 4 humors & the idea of bloodletting
- James I's royal physician
- Wrote *On the Motion of the Heart and Blood*

Critical Thinking:

Explain how Paracelsus, Vesalius, & Harvey's theories contradicted those of Aristotle & Galen.

Why were advances in chemistry important in the 16th & 17th centuries?

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Focus Question: What role did women play in the Scientific Revolution?

Women & Science???

- Margaret Cavendish: aristocrat & prominent scientist excluded from scientific societies
- Maria Merian: entomologist who worked in her father's workshop
- Maria Winklemann: most famous female astronomer; educated by father & uncle; married astronomer (Kirch)

Querelles des Femmes

- Arguments of whether women should participate in science or not:
- 1. Prominent male perspective: women incapable of science
 - Brains smaller
 - Easily swayed
 - Needed males to influence them
- 2. Women capable – need an opportunity of equal education & avenue to participate

Critical Thinking:

Which women were able to participate in science? What factors played a significant role?

Focus Question: Why is Descartes considered the “founder of modern rationalism”? How were the ideas of the Scientific Revolution spread, and what impact did they have on society and religion?

Rene Descartes (1596-1650)

- Began philosophy when found himself “saddled with so many doubts & errors that I seemed to have gained nothing in trying to educate myself unless it was to discover more & more fully how ignorant I was.”
- Felt all beliefs of past were worthless – except religion
- Not put faith in Aristotle & ancient books & attacked medieval scholastic methods
- All nature reduced to math
- **Deductive** = general to specific
- **Cartesian Dualism**: b/n man & mind “I think therefore I am”
- Father of modernity & founder of the school of **rationalism** = perceives reality from a starting point in the human mind
- **Systematic Doubt**: doubt everything that can be doubted
- Truth not something found at the beginning, but something found at the end of long process of inquiry

Critical Thinking:

Create a diagram that demonstrates the differences between Descartes & Bacon.

Francis Bacon (1561-1626)

- 1st leader of Scientific Revolution
 - 1620 completed Novum Organum: new method of acquiring knowledge = **inductive method**
 - Particular→general - concrete→abstract
 - Knowledge based on observed fact
 - Philosopher of **Empiricism**: Knowledge on observation & experience

Focus Question Answer: