THE SCIENTIFIC REVOLUTION

Note: The new Curriculum Framework places the Scientific Revolution in Period 1: 1450-1648. Some teachers, however, may prefer to cover the Scientific Revolution and the Enlightenment together later in the first semester.

I. The Scientific Revolution

A. Medieval view of the world
   1. It was primarily religious and theological.
   2. Political theory was based on the divine right of king.
   3. Society was largely governed by Church views, traditions, and practices.
   4. Superstition played major role in the everyday lives of the people.
   5. Scientific thought in the early-16th century was still based on Medieval ideas.
      a. Views about the universe were largely influenced by the ancient ideas of Aristotle.
      b. The geocentric view held that the earth was the center of a static, motionless universe.
      c. Science was essentially a branch of theology.

B. Causes of the Scientific Revolution
   1. Medieval universities provided the framework.
      a. By 1300, philosophy had become an accepted discipline (in addition to law, medicine, and theology).
      b. Medieval philosophers developed a degree of independence from theologians and a sense of free inquiry.
      c. Leading universities established new professorships of mathematics, astronomy, and physics (natural philosophy) within their departments of philosophy.
      d. Major scientific figures either studied or taught at universities.
   2. The Renaissance stimulated science by rediscovering ancient mathematics.
      • Renaissance patronage was often scientific as well as artistic and humanistic.
   3. Navigational problems on sea voyages in the age of overseas expansion created a need for scientific advances.
      a. New instruments: telescope, barometer, thermometer, pendulum clock, microscope, and air pump
      b. Gresham College, England: scientists worked closely with top officials in the Royal Navy and leading merchants and shipbuilders
         • It became the main center of scientific activity during the first half of 17th century.
4. **Scientific methodology.**
   a. Bacon formalized empirical, experimental research.
   b. Descartes emphasized deductive reasoning.

C. The Scientific Revolution became the major cause of the new world view of the 17th and 18th centuries.
   1. Secularism emerged and many educated people became openly hostile to religion.
   2. The revolution in learning became a major foundation in Western society.

II. **Astronomy**
   A. 16th Century
   1. **Nicolaus Copernicus** (1473-1543)
      a. *On the Revolutions of Heavenly Spheres* (1543)
         - Copernicus postponed publication of his book fearing a backlash by the scientific community.
         - He dedicated the book to Pope Paul III and did not intend for his theories to challenge Church doctrine.
      b. **Heliocentric view:** He argued that the earth revolved around the Sun and that the sun was the center of the universe.
         - He observed that the stars did not move although the apparent movement of the stars was the result of the earth’s rotation.
         - The universe now seemed enormous, perhaps infinite.
         - A major anomaly in his theory, retrograde motion of planets relative to the earth’s position, was remedied by the false premise of epicycles.
         - Copernicus directly challenged Ptolemy’s 2nd-century A.D. view of a geocentric universe.
         - Heliocentrism seemed to challenge the Bible’s Book of Genesis that put forth a geocentric view.
      c. Religious reaction to the Copernican theory
         - Martin Luther and John Calvin condemned Copernicus’ theory; they pointed to Biblical passages supporting the medieval view of geocentrism.
         - Catholic reaction was initially less forceful as the Church didn’t always interpret the Bible literally.
         - Yet, by 1616 the Catholic Church had proclaimed the Copernican theory as false and persecuted those who advanced his views (e.g., Galileo).
   2. **Tycho Brahe** (1546-1601)
      a. Europe’s leading astronomer in the late-16th century
      b. He built the best observatory in Europe and for decades collected massive data on his observations of the universe.
         - This data became a cornerstone of astronomy for centuries.
      c. His data later proved Copernicus’ theory.
         - Ironically, Brahe did not accept the Copernican theory; he believed that while the planets all revolved
around the sun, the sun revolved around the earth.

3. **Johannes Kepler** (1571-1630)
   a. He was the first great Protestant scientist who earlier had worked as an assistant to Brahe.
   b. **Mathematically, he proved the Copernican theory.**
   c. **He developed three laws of planetary motion:**
      - The orbits of planets are elliptical (not circular).
      - Planets do not move at uniform speed while in their orbits.
      - The time it takes for a planet to orbit the sun is directly based on its distance from the sun.
        - The closer a planet is to the sun (e.g. Mercury and Venus) the faster its orbit will be.

B. Astronomy in the 17th Century
   1. **Galileo Galilei** (1564-1642)
      a. He developed the **laws of motion.**
         - He used the experimental method (with controlled experiments).
         - Acceleration experiment: gravity was a universal force that produced uniform acceleration.
           - All falling objects descend with equal velocity regardless of their weight.
         - Law of inertia: an object that is in motion remains in motion until it is stopped by some external force.
      b. **He validated Copernicus’ heliocentric view with the aid of a telescope.**
         - Galileo was the first to use the telescope as a scientific instrument; he built one himself.
         - He demonstrated that the moon and other planets were not perfectly round orbs like a crystal sphere (the prevailing medieval view).
         - He discovered the 4 moons of Jupiter thus refuting the notion that Jupiter was embedded in an impenetrable crystal sphere.
      c. **Galileo’s findings became controversial in Catholic countries.**
         - His views were largely supported in Protestant northern Europe where reformers had questioned Catholic doctrines.
         - The Catholic Church in 1616 declared the Copernican theory to be heretical.
         - In 1632, Galileo published *Dialogue Concerning the Two Chief World Systems* in which he wrote about the Copernican system as a mathematical proposition.
         - In 1633, the inquisition of Pope Urban VII forced Galileo to retract his support of the Copernican theory.
           - He remained under house arrest for the rest of his life.
2. **Isaac Newton** (1642-1727)
   a. He incorporated the astronomy of Copernicus and Kepler with the physics of Galileo into an overarching theory explaining order and design to the universe.
   b. **Principle of universal gravitation**:
      - Detailed in *Mathematical Principles of Natural Philosophy*, (1687). (It was known more popularly as *Principia*).
      - Perhaps the greatest book on science ever written
      - The natural laws of motion – gravitation – are evident in the movement of heavenly bodies and earthly objects.
      - Newton developed a set of mathematical principles to explain motion.
      - *Every body in the universe attracts every other body in the universe* in a precise mathematical relationship
      - Since these natural laws are unchangeable and predictable, God’s active participation in the natural world is not needed to explain the forces of nature.
         - This directly challenged medieval beliefs.
         - This view came to be the foundation of the Enlightenment view of God: deism.
   c. He invented calculus in order to complete his theory (although Leibniz also claimed to have done so).

III. The **Scientific Method**

A. **Francis Bacon** (1561-1626)
   1. He formalized the empirical method (or empiricism) that had already been used by Brahe and Galileo.
   2. **Inductive method** for scientific experimentation:
      - Begin with inductive observation, then form a hypothesis, conduct experiments and then organize the data.
      - “Renounce notions and begin to form an acquaintance with things.”
      - Bacon’s inductive method, coupled with Descartes deductive reason formed the backbone of the modern scientific method.

B. **René Descartes** (1596-1650)
   1. **Discourse on Method** advocated the use of deductive reasoning.
      a. He employed deductive reasoning to prove his existence: "*cogito ergo sum*" ("I think, therefore, I am")
         - His proof depended on logic alone.
      b. He believed science must:
         - Start with clear and incontrovertible facts.
         - Subdivide each problem into as many parts as necessary, using a step-by-step logical sequence.
   2. He demonstrated the relationship between algebra and geometry and developed analytical geometry.
   3. **Cartesian Dualism** divided all existence into the spiritual and the material.
      - The spiritual can only be examined through deductive
reasoning (logic).

- The material is subject to the experimental method.

C. **Modern Scientific Method**: inductive method (of Bacon) + the deductive method (of Descartes)

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<th>Memory Device for Astronomy in the Scientific Revolution:</th>
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<td>C ops Copernicus</td>
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IV. Anatomy, physiology, and biology

A. Scientists began challenging traditional Greco-Roman medical theories of health and disease, such as the 2nd century Roman physician, Galen.
   1. He believed a proper balance of the four humors—blood, phlegm, black bile, and yellow bile—were the basis for human health.
   2. Blood-letting was a common method used to place the humors back into proper balance.

B. **Paracelsus** (1493-1541)
   1. Swiss physician and alchemist
   2. He was a pioneer in the experimental method in medicine.
   3. He experimented with the use of various chemicals and drugs to deal with medical issues that he saw as chemical imbalances, rather than humoral imbalances.

C. **Vesalius** (1516-1564): *The Structure of the Human Body* (1543)
   1. Flemish physician
   2. His book renewed and modernized the study of human anatomy.
   3. It included about 200 detailed drawings that ushered in a revolution in the understanding of the human body.
   4. He dissected cadavers (many of whom had been criminals) to achieve stunning detail in his drawings.
   5. He was the first to assemble human skeletons.

D. **William Harvey** (1578-1657)
   1. English royal physician
   2. *On the Movement of the Heart and Blood* (1628): Explained how blood was pumped by the heart and circulated throughout the body via veins and arteries.
E. Anton van Leeuwenhoek (1632-1723)
1. “Father of microscopy”: he developed powerful microscopes.
2. He was first to see and write about bacteria, yeast plants, living organisms in a drop of water and the circulation of blood corpuscles in capillaries.

F. Royal scientific societies
1. Governments/monarchs encouraged scientific inquiry as a means to further the prestige of the state and remain at the cutting edge of technology.
2. Scientific societies created a means by which scientists could communicate with each other internationally; this helped forge an international scientific community.
3. The Royal Society in England was perhaps the most successful and prestigious; founded in 1660
4. Other royal societies were created in Naples, France (by Louis XIV), Prussia (by Frederick I) and Russia (by Peter the Great).

G. Impact of the Scientific Revolution on Society
1. Led directly to the Enlightenment of the 18th century (see 2.4 notes)
2. Improvements in exploration (e.g. John Harrison’s chronometer gave mariners the ability to easily determine longitude by the late-18th century)
3. Spirit of experimentation helped accelerate the agricultural revolution near the turn of the 18th century.
4. Improvements in medical knowledge helped improve the quality of life later (19th and 20th centuries)
5. Reduced the support for witch hunts by discrediting superstition and witchcraft as fallacies.
6. Science and religion were not in acute conflict until the 19th and 20th centuries.
a. There were few attempts in 17th and 18th centuries to secularize science.
   • Scientists believed they were studying and analyzing God’s creation.
   • Universal agreement existed among scientists and philosophers regarding the supernatural origin of the universe.
   • Debate centered on the extent to which God continued to be involved in His Creation.
b. After the Catholic Counter Reformation, the Church became more hostile to science and science declined in Italy (but not France).
   • Protestant countries became the leaders of the scientific revolution, especially England.
V. **Alchemy** and **astrology**

A. **Alchemy** and **astrology** continued to appeal to elites and some natural philosophers, in part because they shared with the new science the notion of a predictable and knowable universe.

1. Alchemy was the medieval forerunner of modern chemistry as it dealt with the supposed transformation of matter (as in converting base metals into gold or in finding a universal elixir that would restore one’s youth).
   - No clear line between alchemy and chemistry existed in the 17th and 18th centuries.
2. Paracelsus mixed magic and valid science in ways that defied modern science.
3. Gerolamo Cardano (1501-1576) was a pioneer of algebra who also subscribed to alchemy.
4. Both Brahe, and his protégé, Kepler, believed in alchemy; Brahe even had a laboratory dedicated to its study.
5. Isaac Newton believed in principles of alchemy as he devised his theory of universal gravitation. He devoted more time writing about alchemy than to either optics or physics.

B. **Astrology**

1. Prominent leaders, such as Queen Elizabeth of England, paid astrologers to forecast their future.
3. Brahe was the court astrologer in Denmark; Kepler was the astrologer to the Austrian Habsburgs, and Galileo provided horoscopes to the Medici.
4. Astrology experienced a decline during and after the Enlightenment in the 18th century.

C. In the oral culture of peasants, a belief that the cosmos was governed by divine and demonic forces persisted.

1. Everything in the universe—people, the world—seemed interconnected.
2. Astrology coexisted with religion, magic, and science.
3. The persistent belief in magic was one reason the witch hunts continued well into the 17th century.
Terms to Know

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<td>Rene Descartes</td>
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Essay Question

*Note: This sub-unit is a high probability area for the AP exam. In the past 10 years, 8 questions have come wholly or in part from the material in this chapter. Below is a broad question that will help you study the topics that have appeared on previous exams.*

1. How did the Scientific Revolution impact European society intellectually, politically, religiously, and economically?
Bibliography:

**Principle Sources:**
College Board, *AP European History Course and Exam Description (Including the Curriculum Framework)*, New York: College Board, 2017

**Other Sources:**