The Scientific Revolution and the Emergence of Modern Science

Chapter 16 / 17

The Trial of Galileo Galilei in the Vatican
During the Enlightenment, the ideas of the Scientific Revolution were spread and popularized in a variety of ways.

Scientific societies funded by royal and princely patrons were especially valuable in providing outlets for the spread of new scientific ideas.

This illustration shows the German prince Frederick Christian visiting his Academy of Sciences in 1739.

Note the many instruments of the new science around the rooms—human skeletons, globes, microscopes, telescopes, and orreries (mechanical models of the solar system).
Background to the Scientific Revolution

- Ancient Authors and Renaissance Artists
  - Limitations in the perspectives of medieval scientists
  - The Renaissance and ancient knowledge
    - Contradictions of medieval authorities
    - Close observation of nature
    - Perspective and anatomical proportions
Background to the Scientific Revolution

- Technological Innovations and Mathematics
  - Creating a framework for innovation
- Renaissance “Magic”
  - Hermetic magic and alchemical thought

Going away from older pagan ideas
Toward a New Heaven: a Revolution in Astronomy

- Medieval Cosmological Views
  - Based on Aristotle, Ptolemy, and Christian theology
  - **Geocentric** conception
    - Concentric spheres with fixed earth at center
Nicolaus Copernicus (1473 – 1543)

- *On The Revolution of the Heavenly Spheres*
  - Observation and *heliocentric* conception
    - The conservatism of Copernicus
  - Creates doubt about the Ptolemaic system
Medieval Conception of the Universe

As this sixteenth-century illustration shows, the medieval cosmological view placed the earth at the center of the universe, surrounded by a series of concentric spheres.

The earth was imperfect and constantly changing, whereas the heavenly bodies that surrounded it were perfect and incorruptible. Beyond the tenth and final sphere was heaven, where God and all the saved souls were located. (The circles read, from the center outward: 1. Moon, 2. Mercury, 3. Venus, 4. Sun, 5. Mars, 6. Jupiter, 7. Saturn, 8. Firmament (of the Stars), 9. Crystalline Sphere, 10. Prime Mover; and around the outside, Empyrean Heaven—Home of God and All the Elect, that is, saved souls.)
The Copernican system was presented in On the Revolutions of the Heavenly Spheres, published shortly before Copernicus’s death.

As shown in this illustration from the first edition of the book, Copernicus maintained that the sun was the center of the universe and that the planets, including the earth, revolved around it.

Moreover, the earth rotated daily on its axis. (The circles read, from the inside out: 1. Sun; 2. Mercury, orbit of 80 days; 3. Venus; 4. Earth, with the moon, orbit of one year; 5. Mars, orbit of 2 years; 6. Jupiter, orbit of 12 years; 7. Saturn, orbit of 30 years; 8. Immobile Sphere of the Fixed Stars.)
Toward a New Heaven: a Revolution in Astronomy

-Tycho Brahe (1546 – 1601)
Abandoning theology in favor of mathematics and astronomy, Kepler became a key figure in the rise of the new astronomy.

Using Tycho Brahe’s vast store of astronomical data, Kepler discovered the three laws of planetary motion that both confirmed and modified the Copernican theory.

They also eliminated the Aristotelian-Ptolemaic ideas of uniform circular motion and crystalline spheres moving in circular orbits.

This portrait was done by an unknown painter three years before Kepler’s death.
Toward a New Heaven: a Revolution in Astronomy

- Johannes Kepler (1571 – 1630)
  - Hermetic thought and mathematical magic
  - Laws of planetary motion
    - Discrediting the Aristotelian-Ptolemaic system
    - Eliminating the idea of uniform circular motion
Toward a New Heaven: a Revolution in Astronomy

- Galileo Galilei (1564 – 1642)
  - The telescope and *The Starry Messenger*
  - Galileo and the Inquisition
  - Galileo and the problem of motion
    - The principle of inertia
The invention of the telescope enabled Europeans to inaugurate a new age in astronomy.

Shown here is Johannes Hevelius (huh-VAY-lee-uss), an eminent German-Polish astrologer (1611–1697), making an observation with his telescope.

Hevelius’s observations were highly regarded. He located his telescope on the roof of his own house, and by the 1660s, his celestial observatory was considered one of the best in Europe.
The photograph shows Galileo’s original telescope, built in 1609.
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.
Isaac Newton (1642 – 1727)

- Early Achievements
  - Invention of calculus
  - *Mathematical Principles of Natural Philosophy, or Principia* (1684 – 1686)
- Newton and the Occult
- Universal Law of Gravitation
  - A new cosmology
    - Three laws of motion
    - Consequences: world seen in mechanistic terms
      - God and Newton’s world-machine
Advances in Medicine and Chemistry

- Paracelsus (1493 – 1541)
  - Rejection of Aristotle and Galen
  - The macrocosmic-microcosmic principle
- Andreas Vesalius (1514 – 1564)
  - *On the Fabric of the Human Body* (1543)
    - Based on dissection of a human body
- William Harvey (1578 – 1657)
  - *On the Motion of the Heart and Blood* (1628)
- Chemistry
  - Robert Boyle (1627 – 1691)
  - Antoine Lavoisier (1743 – 1794)
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<td>Galileo, <em>Dialogue on the Two Chief World Systems</em></td>
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<td>Cavendish, <em>Grounds of Natural Philosophy</em></td>
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<td>Newton, <em>Principia</em></td>
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Descartes was one of the primary figures in the Scientific Revolution.

Claiming to use reason as his sole guide to truth, Descartes posited a sharp distinction between mind and matter.

He is shown here in a portrait done around 1649 by Frans Hals, one of the painters of the Dutch golden age who was famous for his portraits, especially that of Descartes.
Toward a New Earth: Descartes, Rationalism, and a New View of Humankind

- Rene Descartes (1596 – 1650)
  - Reflections on doubt and uncertainty
  - *Discourse on Method* (1637)
    - “I think, therefore I am.”
  - Separation of mind and matter
    - Cartesian Dualism
  - Consequences: the birth of modern rationalism
The Scientific Method and the Spread of Scientific Knowledge

- **The Scientific Method**
  - **Francis Bacon (1561 – 1626)**
    - Rejection of Copernicus and Kepler; Misunderstanding of Galileo
    - *The Great Instauration* and correct scientific method
      - Built on inductive principles, proceeding from the particular to the general
      - Experimentation and domination of nature
  - **Descartes**
    - Deduction and mathematical logic
    - Newton’s unification of Bacon’s empiricism and Descartes rationalism
In the seventeenth century, individual scientists received royal and princely patronage, and a number of learned societies were established.

In France, Louis XIV, urged on by his controller general, Jean-Baptiste Colbert, gave formal recognition to the French Academy in 1666.

In this painting by Henri Testelin, Louis XIV is shown seated, surrounded by Colbert and members of the French Royal Academy of Sciences.
The Royal Observatory at Greenwich

To facilitate their astronomical investigations, both the English and the French constructed observatories such as the one pictured here, which was built at Greenwich, England, in 1675.

Here the royal astronomer works at the table while his two assistants make observations.
The Scientific Method and the Spread of Scientific Knowledge

- The Scientific Societies
  - English Royal Society
    - Informal meetings at London and Oxford
    - Received formal charter in 1662 from Charles II
  - French Royal Academy
    - Informal meetings in Paris
    - Formally recognized by Louis XIV (1666)

- Contributions
  - Recognition of the practical value of scientific research
  - Focus on theoretical work in mechanics and astronomy
The Scientific Method and the Spread of Scientific Knowledge

- **Science and Society**
  - People recognized science’s rational superiority

- **Economic implications**
  - Science offered new ways to exploit resources for profit
    - Science as a part of elite culture

- **Political implications**
  - Linking the scientific conception of the natural world to social stability
  - Patronage to bolster military applications
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<td>Pascal</td>
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<td>Spinoza</td>
<td>Ethics Demonstrated in the Geometrical Manner</td>
<td>1677</td>
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Science and Religion

- Tensions between Science and Religion
- **Blaise Pascal (1623 – 1662)**
  - Sought unity of science and religion
  - *Pensées* (Thoughts)
    - Sought to convert rationalists to Christianity
  - Christianity not contrary to reason
  - Reason had limits
Blaise Pascal was a brilliant scientist and mathematician who hoped to keep science and Christianity united.

In his Penseès, he made a passionate argument on behalf of the Christian religion.

He is pictured here in a portrait by Philippe de Champaigne, a well-known French portrait painter of the Baroque period.
The Enlightenment

- The Paths to Enlightenment
  - “Dare to know”: Immanuel Kant (1724 – 1804)
  - The popularization of science
  - A new skepticism
    - Pierre Bayle (1647 – 1706)
    - Skepticism about religion and growing secularization
  - The impact of travel literature
    - Captain James Cook
    - The “noble savage” and cultural relativism
The Philosophes and Their Ideas

- The Philosophes
  - Diverse backgrounds, common bonds
    - Desire to change the world
    - Freedom of expression and a spirit of rational criticism
- Charles de Secondat, Baron de Montesquieu (1689 – 1755), and Political Thought
  - *The Spirit of the Laws*, 1748
    - “Separation of powers”
“Have the courage to use your own intelligence!”

Kant’s words epitomize the role of the individual in using reason to understand all aspects of life—the natural world and the sphere of human nature, behavior, and institutions.
The Philosophes and Their Ideas

- Voltaire (1694 – 1778) and the Enlightenment
  - *Philosophic Letters on the English* (1733)
    - Indictment of French absolutism
  - Criticism of traditional religion and intolerance
    - The Calas affair
    - *Treatise on Toleration*, 1763
    - Deism
François-Marie Arouet, better known as Voltaire, achieved his first success as a playwright.

A philosophe, Voltaire was well known for his criticism of traditional religion and his support of religious toleration.

Maurice-Quentin de La Tour painted this portrait of Voltaire holding one of his books in 1736.
The Philosophes and Their Ideas

- **Denis Diderot** (1713 – 1784) and the Encyclopedia
  - Goal: “change the general way of thinking”
  - Contributors to 28-volume collection expressed major concerns
    - Attacks on religious superstitions
    - Advanced a program for social, legal, and political improvements
  - Lowered price helped spread Enlightenment ideas
The Philosophes and Their Ideas

- The New “Science of Man”
  - David Hume (1711 – 1776)
  - **Adam Smith (1723 – 1790)** and *laissez-faire* economics
    - *The Wealth of Nations*, 1776

- Promotion of free trade
- Government has only three basic functions
  - Protect society from invasion
  - Defend individuals from injustice and oppression
  - Keep up public works
The Philosophes and Their Ideas

- Jean-Jacques Rousseau (1712 – 1778) and the Social Contract
  - *Discourse on the Origins of the Inequality of Mankind*
    - Preservation of private property enslaved people
  - *Social Contract* (1762)
    - Attempt to harmonize individual liberty with governmental authority
    - Governance by the general will
By the late 1760s, a new generation of philosophes arose who began to move beyond and even to question the beliefs of their predecessors.

Of the philosophes of the late Enlightenment, Rousseau was perhaps the most critical of his predecessors.

Shown here is a portrait of Rousseau by Maurice-Quentin de La Tour.
The Social Environment of the Philosophes

- The Spread of Enlightenment Ideas
  - Appeal to aristocracy and upper middle classes
    - Common people little affected by the Enlightenment
  - The importance of publications and salons
    - Other gathering places: coffeehouses, cafés, reading clubs, and public lending libraries
## CHRONOLOGY Works of the Philosophes

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<tr>
<th>Work</th>
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<td>Voltaire, <em>The Age of Louis XIV</em></td>
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<td>Diderot, <em>Encyclopedia</em></td>
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<td>Rousseau, <em>The Social Contract; Émile</em></td>
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<td>Voltaire, <em>Treatise on Tolerance</em></td>
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<td>Beccaria, <em>On Crimes and Punishments</em></td>
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<td>Holbach, <em>System of Nature</em></td>
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<td>Smith, <em>The Wealth of Nations</em></td>
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<td>Gibbon, <em>The Decline and Fall of the Roman Empire</em></td>
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<td>Wollstonecraft, <em>Vindication of the Rights of Woman</em></td>
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<td>Condorcet, <em>The Progress of the Human Mind</em></td>
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Culture and Society in the Enlightenment

- Innovations in Art, Music, and Literature
  - Rococo
    - Antoine Watteau (1684 – 1721)
    - Fragility and transitory nature of pleasure, love, and life
  - Baroque-Rococo architectural style
    - Balthasar Neumann (1687 – 1753)
    - Secular and spiritual interchangeable
  - Continuing appeal of Neoclassicism
    - Jacques-Louis David (1748 – 1825)
Balthasar Neumann, one of the most prominent architects of the eighteenth century, used the Baroque-Rococo style to design some of the most beautiful buildings of the century.

Pictured here is the exterior of his pilgrimage church of the Vierzehnheiligen (Fourteen Saints), located in southern Germany.
Pictured here is the interior of the Vierzehnheiligen, the pilgrimage church designed by Balthasar Neumann.

Elaborate detail, blazing light, rich colors, and opulent decoration blend together to create a work of stunning beauty.

The pilgrim in search of holiness is struck by an incredible richness of detail.

Persuaded by joy rather than fear, the believer is lifted toward heaven on a cloud of rapture.
Innovations in Literature

- The Writing of History
  - Broadening the scope of history
    - Voltaire’s *Age of Louis XIV*
    - Edward Gibbon (1737 – 1794)
  - *Decline and Fall of the Roman Empire*
Innovations in Art, Music, and Literature

- The Development of Music
  - Domination of Baroque style (1600 – 1750)
    - Johann Sebastian Bach (1685 – 1750)
    - George Frederick Handel (1685 – 1759)
  - The classical era (1750 – 1830)
    - Franz Joseph Haydn (1756 – 1809)
    - Wolfgang Amadeus Mozart (1756 – 1791)
Mozart (Tom Hulce) meets with Salieri (F. Murray Abraham)
The High Culture of the Eighteenth Century

- Characteristics
  - Increased readership and publishing
  - Development of magazines and newspapers for the general public
    - Daily newspapers
- Education and Universities
  - Perpetuated class hierarchy of Europe
    - Concentration on the classics
    - New middle class education
A London Coffeehouse

Coffeehouses first appeared in Venice and Constantinople but quickly spread throughout Europe by the beginning of the eighteenth century.

In addition to drinking coffee, patrons of coffeehouses could read magazines and newspapers, exchange ideas, play chess, smoke, and engage in business transactions.

In this scene from a London coffeehouse of 1705, well-attired gentlemen make bids on commodities.
Crime and Punishment

- Punishment in the Early Eighteenth Century
  - Emphasis on torture and public spectacle

- The Enlightenment Approach to Justice
  - Cesare Beccaria (1738 – 1794), *On Crimes and Punishments*
    - Punishment should serve only as deterrent
    - Punishment moved away from spectacle towards rehabilitation
  - Decline in both corporal and capital punishment by end of the century
    - The emergence of the prison
The World of Medicine

- Practitioners and Their Hierarchy
  - Importance of education for physicians
    - University of Leiden: introduction of clinical experience
    - England’s Royal College of Physicians
  - Barber-surgeons: division
  - Apothecaries, midwives, and faith healers
    - Service to commoners
  - Hospital conditions
    - Appeals for reform ineffectual
Popular Culture

- Literacy and Primary Education
  - Spread of literacy
  - State-supported primary schools
  - Connections between religion and education
Religion and the Churches

- The Institutional Church
  - Conservatism of Catholic and Protestant Churches
  - Church-State Relations
    - The growth of state control
    - The end of the Jesuits
- Toleration and Religious Minorities
- Toleration and the Jews
  - Some Enlightenment thinkers favored acceptance of the Jews
  - Joseph II: limited reforms toward the Jews
Religious Populations of Eighteenth-Century Europe
Popular Religion in the Eighteenth Century

- **Catholic Piety**
  - Highly selective in nature
  - Popular devotion: the appeal of traditional ideas and practices

- **Protestant Revivalism: Pietism**
  - Count Nikolaus von Zinzendorf (1700 – 1760)

- **John Wesley (1703 – 1791) and Methodism**
  - The power of emotional mysticism
  - Brought the Gospel to the people
    - Methodist societies and the split from the Anglican Church
In leading a deep spiritual revival in Britain, John Wesley founded a religious movement that came to be known as **Methodism**.

He loved to preach to the masses, and this 1766 portrait by Nathaniel Hone shows him as he might have appeared before a crowd of people.