Chapter 16 – The Scientific Revolution and Modern Science

Background to the Scientific Revolution

Late medieval scholastic philosophers had pursued mathematical and physical thinking
- Ancients such as Aristotle, Ptolemy, and Galen were trusted – perhaps too much
- Following strict Church guidelines limited exploration
- What we now call scientists were called *natural philosophers* then

Ancient Authors and Renaissance Artists

- Renaissance exploration of Greek texts revealed authors other than Aristotle, Galen, Plato
- Renaissance artists' very close observation of nature set new standards for the study of natural phenomena

Technological Innovation and Mathematics

- The need for accurate measurement (for example) spurred technological innovation
  - e.g., telescope, microscope
- Spread of books reinforced both need and information
- Renaissance rediscovery of Greek texts promoted mathematics
  - Da Vinci believed that nature was inherently mathematical

Renaissance Magic

- Hermetic magic played a role in viewing the natural world
  - Alchemy, astrology, mathematical magic could be used to control nature for beneficial purposes
  - Copernicus, Kepler, Galileo, Newton all were interested in hermetic ideas

Toward a New Heaven: A Revolution in Astronomy

Greatest 16th- and 17th-century achievements were in traditional subjects of ancient Greek philosophers
- Astronomy, mechanics, and medicine
- Aristotle, Ptolemy, and Christian theology resulted in a ***geocentric conception*** of the universe
  - Earth (made up of earth, air, fire, and water) was imperfect and changing
  - Crystal spheres (there were 10) surrounding the earth moved in circular orbits
    - Heavenly bodies (stars, planets) were embedded in the spheres
  - Beyond the spheres was "heaven"
- Professional astronomers did not accept this; it disagreed with observations
  - They invented elaborate systems of "fixes" (epicycles) to explain it all

Copernicus (1473-1543)

- Well read and well-studied, but couldn't accept Ptolemaic view
  - Wrote *On the Revolution of the Heavenly Spheres* but wouldn't publish it until shortly before his death
  - Not an astronomer but a mathematician who relied on others' observations
- Proposed a sun orbited by eight planets, the moon was an earthly satellite, and the earth rotated on an axis
- Was a Catholic monk – and was first attacked by Protestant literalists
  - Uncertainty as to God's place in all this
  - Luther and Melanchthon condemned him
    - Catholic Church didn't condemn him until Galileo's work appeared

Brahe (1546-1601)

- Was the foundation for Kepler's later work
- Granted a laboratory/island
  - By the Danish king
  - on which he built a library and observatory and provided instruments
  - from which he made nightly observations for twenty years
- hired Kepler as an assistant

Kepler (1571-1630)

- While studying theology at university, he fell in with Mästlin (Germany's most famous astronomer)
  - Believer in Hermetics, wrote a book on astrology that maintained the universe was constructed geometrically
  - Tried to discover the "music of the spheres"
  - Using Brahe's observations, he proposed the laws of planetary motion
    - They confirmed Copernicus – except that orbits were elliptical

The sun was at a focus of those elliptical orbits (not at the center)
Larger planets traveled more slowly than smaller ones

Galileo (1564-1642)

First to systematically study the heavens with a telescope
Mountains and craters on the moon, four moons revolving around Jupiter, sunspots
Published *Starry Messenger* (1610)
Ran into Catholic opposition (in the form of the Roman Inquisition)
Was told he could only propose it as a theory
Wrote *Dialogue on the Two Chief World Systems*
A "conversation" between a dull follower of Ptolemy and a sharper follower of Copernicus

Galileo and the Problem of Motion

Countered Aristotle's ideas of objects in motion stop when force is removed
A state of uniform motion is as natural as state of rest
Roman Inquisition resulted in the decrease of Italy's influence in the scientific world

Newton (1642-1727)

1666: plague sent him home from Cambridge
invented calculus, investigated the composition of light, began research on universal gravitation
1686: published *Principia Mathematica (Mathematical Principles of Natural Philosophy)*

Newton and the Occult

Seriously studied alchemy

Universal Law of Gravitation

Three laws of motion
1) bodies in motion, bodies at rest…
2) rate of change of motion is proportional to the force acting on it
3) for each action there is an equal and opposite reaction
applied these laws to the celestial world
the universe was a regulated, uniform machine

Advances in Medicine and Chemistry

Prior to the Scientific Revolution, Galen's ideas of anatomy, physiology, and disease were paramount
Treatment of disease was based on a balance of the "four humors": blood, yellow bile, black bile, and phlegm

Paracelsus (1493-1541)

Actually named Philippus Aureolus von Hohenheim, from Switzerland
Rejected Galen: disease was caused by chemical imbalances in specific organs
Could be treated with chemical remedies
Dosage mattered, because toxins in the correct amount could cure

Vesalius (1514-1564)

Discovery of a Galen work prompted him to look at practical research
Gained a degree from University of Padua, began teaching there
1543: published *On the Fabric of the Human Body*
based on his lectures, personal dissections
contained illustrations (dependent on Renaissance art, printing press)

William Harvey (1578-1657)

1628: published *On the Motion of the Heart and Blood*
circulation system begins and ends with the heart
the same blood flows in the veins and arteries

Chemistry

Robert Boyle (1627-1691) employed carefully controlled experiments
Worked on the properties of gases
Boyle's Law: volume of gas varies with the pressure exerted upon it
Believed that there were different atoms (later called "elements")
Anton Lavoisier (1743-1794) invented a system of naming chemical elements

Women in the Origins of Modern Science

Elite women in the seventeenth century had the opportunity for education
Often helped their fathers, brothers or husbands, were educated

Margaret Cavendish (1623-1673)

Aristocratic, educated
Published essays, argued about substance

Maria Merian (1647-1717)

Arose from the *craft tradition* of women
Father studied entomology; she developed skill of illustration
Eventually went to Suriname (published – with illustration)

Maria Winkelman (1670-1720)

Educated by her father and uncle in astronomy
Married an astronomer, assisted him
Discovered independently, corresponded with famous scientists
Was turned down by Berlin Academy
Echoed refusal of Royal Society of England and French Academy of Sciences to admit women

Debates on the Nature of Women

Centuries-old debate: ***querelles des femmes*** (arguments about women)
Women portrayed as inherently base, prone to vice, easily swayed, and "sexually insatiable"
Women argued that they were rational, education was the key to their ability to move into the world
Actually, science was used to confirm existing bias
Vesalius saw no difference in the skeletons of men and women
Eventually (it took until the 18th century) differences "confirmed" things:
Women's skulls were smaller
Women's larger pelvis was proof that they were meant for only child-bearing
Midwifery (one of the few areas of female influence) was replaced by "professional" doctors

Toward a New Earth: Descartes, Rationalism, and a New View of Humankind

René Descartes began with doubt and uncertainty and ended with a philosophy
Volunteered for the Thirty Years' War, but he seemed to want to travel and reflect
Had a "mystic" experience that saw a new rational-mathematical system
1637: published *Discourse on Method*, signaling his "starting over" to rethink everything
would accept only those things that *reason* said were true (based on "I think, therefore I am" – *cogito ergo sum*)
Cartesian dualism (mind/body *or* mind/matter)
Placed him as "father of materialism" and on the Index of Forbidden Books
Upset conventional views of religion, human nature

The Scientific Method and the Spread of Scientific Knowledge

Universities expanded their inquiry into science, particularly medicine

The Scientific Method

Francis Bacon (1561-1626):

responsible for influencing the Royal Society in the 1600s and Europe in the 1700s
Didn't accept the work of Copernicus and Kepler – and misunderstood Galileo
Called for a new way of pursuing science: an inductive method of reasoning
Move *from the particular to the general* (through experiments and careful observation)
Preferred practical science to "pure science"
Hoped science would lead to man's dominion over the earth

René Descartes (1596-1650)

preferred deduction and mathematical logic
Begin with *general* self-evident truths and deduce their complexities (their *particular* application)

Isaac Newton

combined the two approaches
Begin with systematic observations, move to general concepts, and then apply the concepts to new situations

The Spread of Scientific Knowledge

The Scientific Societies

English Royal Society gained a formal charter from Charles II in 1662
French Academy of Sciences was formally recognized by Louis XIV in 1666
Louis gave substantial financial support
French model was more widely copied throughout Germany
These societies flourished on a model of cooperation among scientists
1665: Scientific Journals began
Royal Society's *Philosophical Transactions*
French Academy's *Journal des Savants*

Science and Society

Science influenced later developments (e.g., the Industrial Revolution)
Some scientists (like Galileo) tried to push innovation in profitable areas
Some scientists (like Galileo) tried to push that understanding science be limited to the elite

Science and Religion

Some science (like Galileo's) threatened theology's status as the "queen of sciences"
Though religious, Galileo said that the church's belief in Biblical texts had little to do with physical reality
Catholic Church's opposition led scientists to "have to choose" between religion and scientific "proof"

Benedict de Spinoza (1632-1677)

An Amsterdam Jew who was excommunicated from his synagogue for rejecting Orthodox Judaism
Read scientific literature and was (negatively) influenced by Descartes
Rejected dualism
Posthumously published *Ethics Demonstrated in the Geometric Manner*
All is God; nothing can be separated from God
Humans cannot be separated from God
So nature cannot exist to serve mankind
Everything has a rational explanation
Natural disasters, human emotions and folly
But humans attempt to blame God or each other
Reason can bring true happiness; real freedom comes from understanding order and necessity of nature

Blaise Pascal (1623-1662)

French scientist who tried to keep science and religion united
Brilliant mathematician (invented calculating machine, devised theories of probability, conic sections)
1654: mystical vision assured him that God cared for the human soul
Wrote *Pensées*
Tried to convert rationalists to Christianity by appealing to *both* reason and emotion
Believed that Christian religion was *not* contrary to reason
In Christianity, humans are both fallen *and* God's special creation
Proposed a famous wager on the existence of God
That God exists is a reasonable bet: if he exists, we win everything; if he doesn't we lose nothing
BUT acceptance of God by reason alone is insufficient
Finite man is lost in an infinite world, and understanding nature does not mean understanding God
HOWEVER, his ultimate dependence on faith (not reason) contributed to the science/religion split