

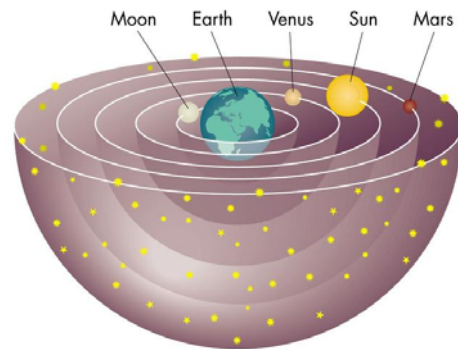
The Scientific Revolution

The “Scientific Revolution” is a concept enunciated by twentieth-century historians of science. It holds that the modern scientific worldview was largely formed in the period between the publication of Copernicus’ heliocentric theory (1543) and the death of Isaac Newton (1727).



Geocentric Model

- Greek: *geo* = earth, *kentron* = center
- In astronomy, the geocentric model of the universe is the theory that the Earth is at the center of the universe and the Sun and other celestial objects go around it.
- Belief in this system was common in ancient Greece. It was embraced by both Aristotle and Ptolemy.

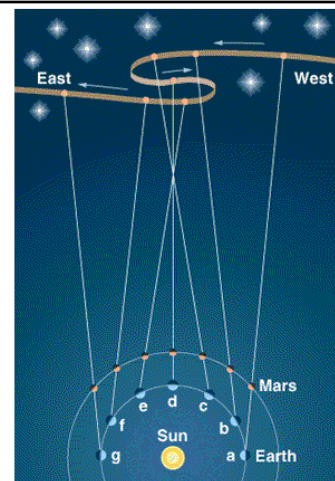


Cross section of Aristotle's universe.

Classical Elements

- Four Elements: Earth, Water, Air, Fire
- And a fifth element (quintessence), *æther*, which is the divine substance that makes up the heavenly spheres and heavenly bodies (stars and planets).
- Each of the elements has its natural place; the earth at the centre of the universe, then water, then air, then fire. When they are out of their natural place they have natural motion, requiring no external cause, which is towards that place; so bodies sink in water, air bubbles rise up, rain falls, flame rises in air.

The Problem of Retrograde Motion

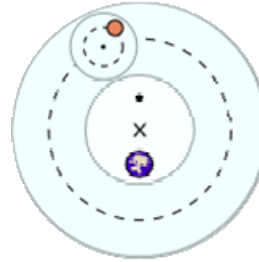


Ptolemy (c. 90-168 AD)

Claudius Ptolemaeus, known in English as Ptolemy, was a Greek-speaking mathematician, geographer, astronomer, and astrologer who lived in the Hellenistic culture of Roman Egypt.



Ptolemaic Astronomy



- A simple illustration showing the basic elements of Ptolemaic astronomy.
- It shows a planet rotating on an epicycle which is itself rotating around a deferent inside a crystalline sphere.
- The center of the system is marked with an X, and the earth is slightly off of the center.
- Opposite the earth is the equant point, which is what the planetary deferent would actually rotate around.

Between Ptolemy and Copernicus

- Christianity
 - Christian theology
 - Eventually, the GCoB
- Islamic Empire
 - Mass translations
 - Original work in science
 - Physics, optics, mathematics, medicine
 - *Al*-words
 - Algebra, algorithm, alchemy, alcohol



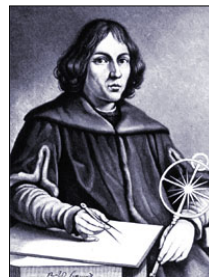
Alchemy

- A medieval form of chemistry whose aims were the transmutation of base metals into gold, the discovery of a cure for all diseases, and the preparation of a potion that gives eternal youth.
 - The imagined substance capable of turning other metals into gold was called the philosophers' stone.

Astronomy vs. Astrology

- Astronomy is the scientific study of celestial objects (such as stars, planets, comets, nebulae, star clusters and galaxies) and phenomena in outer space.
- Astrology is the belief that the positions and aspects of celestial bodies have an influence on the course of human affairs.
- Prior to the scientific revolution, astronomers also made astrological predictions.

Nicolaus Copernicus (1473-1543)


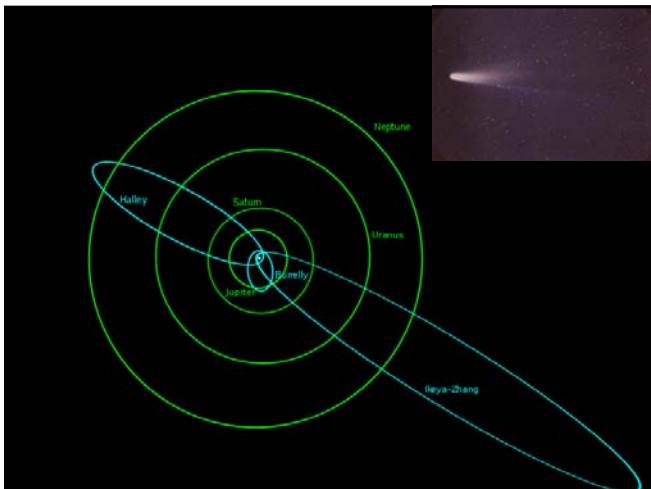
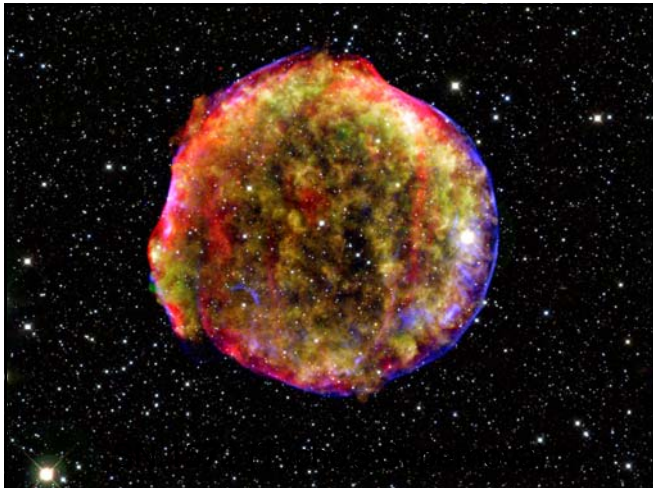
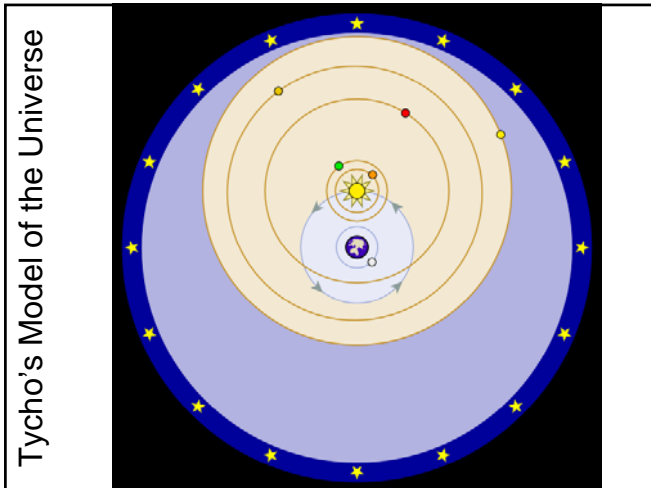


Nicolaus Copernicus was an astronomer who provided the first modern formulation of a heliocentric (sun-centered) theory of the solar system in his book, *De Revolutionibus Orbium Coelestium* (On the Revolutions of the Celestial Spheres, nicknamed *De Rev*, 1543).




Tycho Brahe (1546-1601)

- Danish nobleman famed for his accurate and comprehensive (naked-eye) astronomical observations.
- In trying to prove Copernicus wrong, he found a new 'star', showed comets pierced the heavenly spheres, and provided Kepler with the data Kepler needed to formulate Kepler's laws of planetary motion.

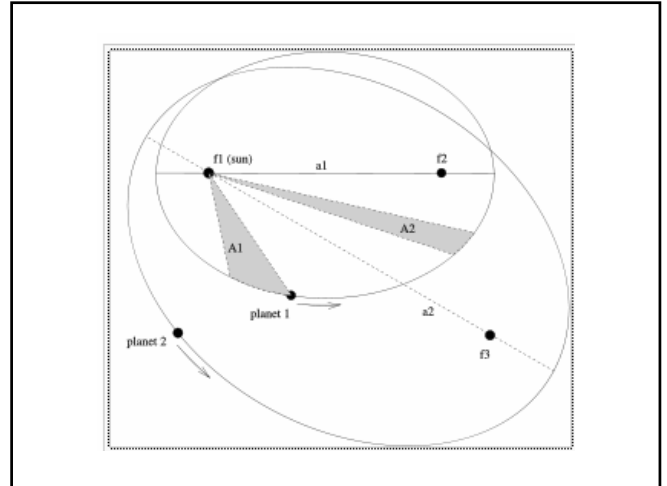
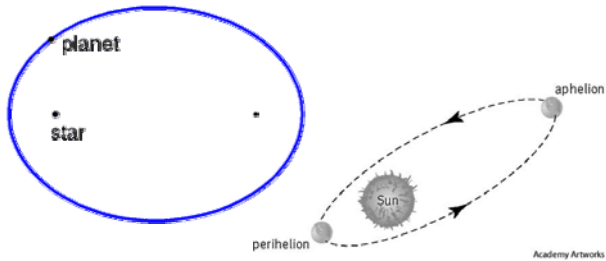
Tycho and Kepler

- Johannes Kepler (1571-1630) studied the observations of the legendarily precise Danish astronomer Tycho Brahe.
- Around 1605, Kepler found that Tycho's observations of the planets' positions followed three relatively simple mathematical laws.



Kepler's First Law of Planetary Motion

- The revolution of every planet is an ellipse with the sun at the center.

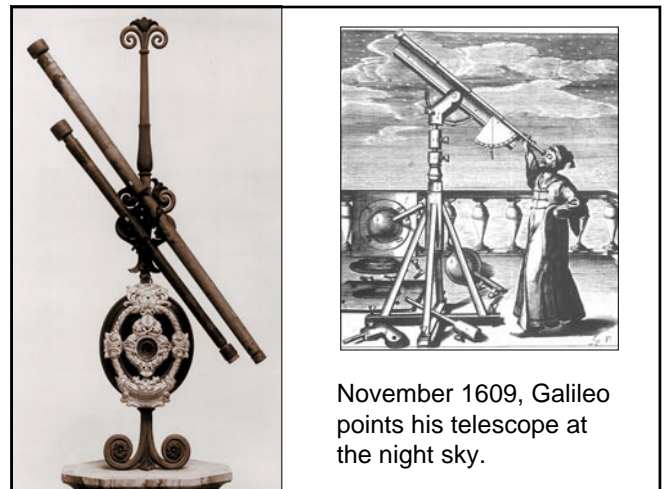
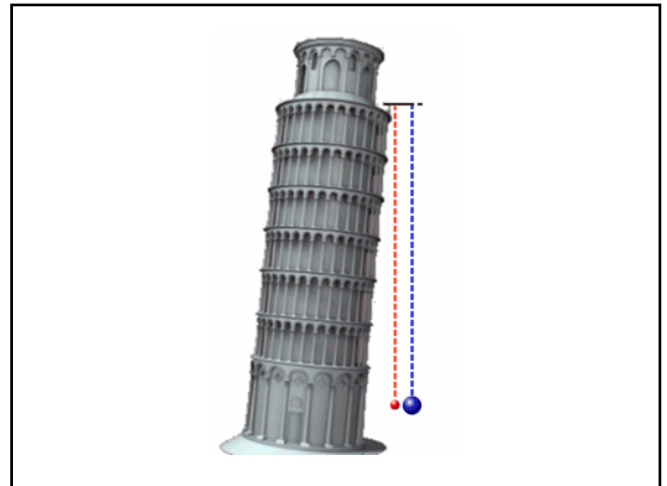


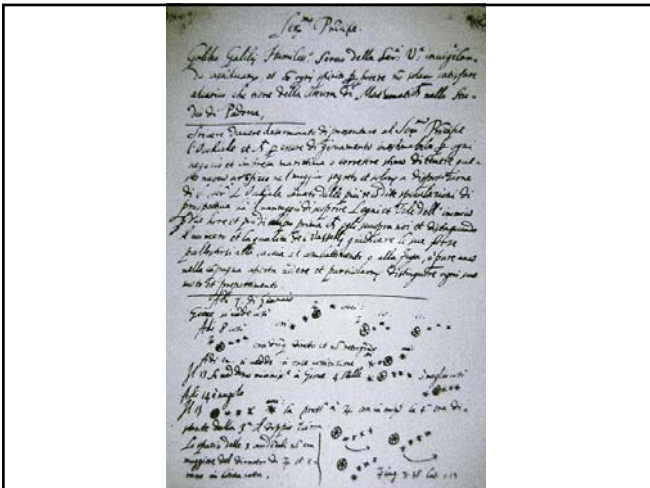
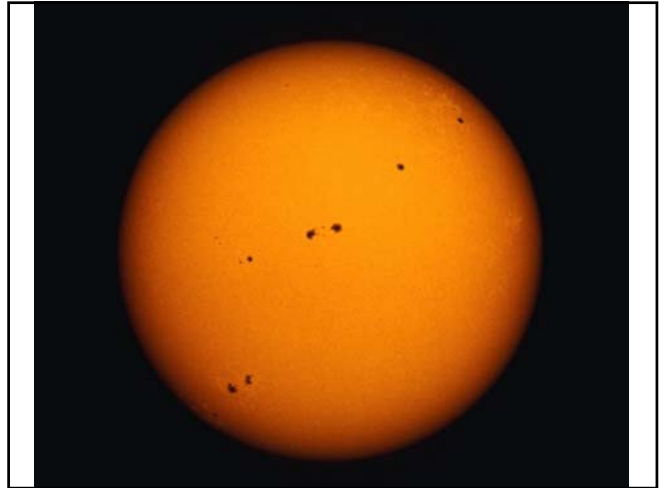
Galileo (1564-1642)

Galileo Galilei was an Italian physicist, astronomer, and philosopher who is closely associated with the scientific revolution.

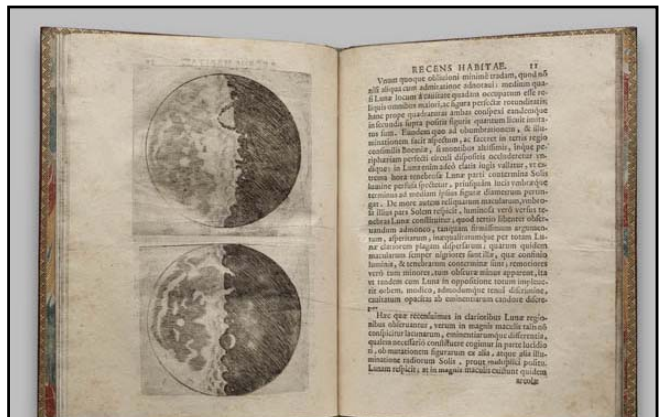


He is most famous for improving the telescope, making original astronomical observations that provided effective support for Copernicanism, and defending those beliefs against prevalent (religious) opinion.





Galileo and Cosimo de' Medici, Grand Duke of Tuscany



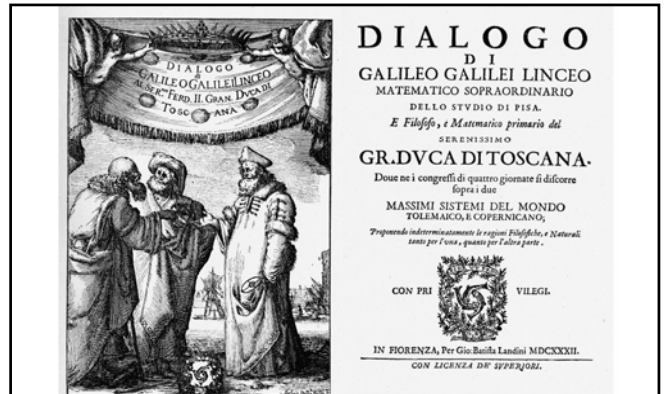
Sidereus Nuncius, 1610 – *Starry Messenger*
<http://www.rarebookroom.org/Control/galsid/index.html>



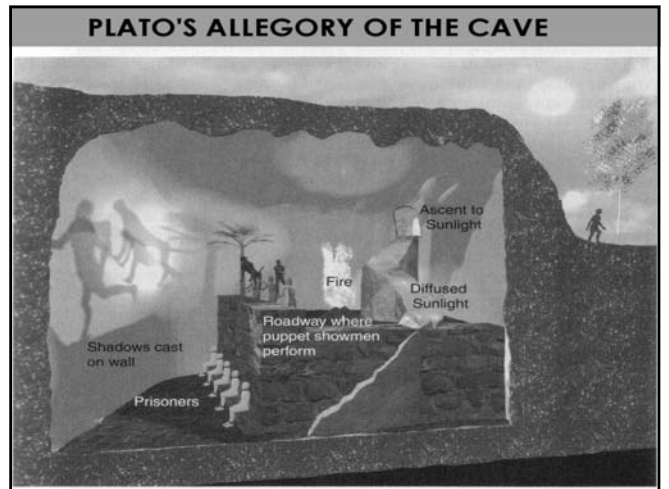
Joshua 10:13 – “The sun stopped in the middle of the sky and delayed going down about a full day.”

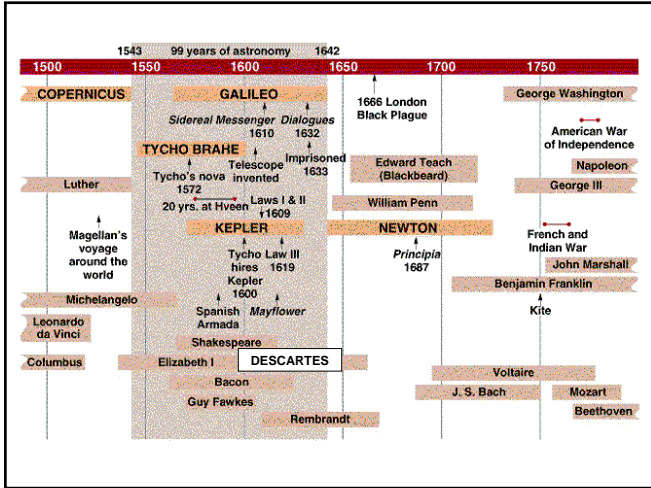


Galileo and Pope Urban VII



The Dialogue Concerning the Two Chief World Systems was a 1632 book by Galileo Galilei which compared the Copernican system to the traditional Ptolemaic system.





A new way of thinking

- Francis Bacon (1561-1626)
- Rene Descartes (1596–1650)
- Robert Boyle, F.R.S. (1629-1691)
- Blaise Pascal (1623–1662)
- Robert Hooke, F.R.S. (1635-1703)
- Antoine Lavoisier (1743–1794)
- Isaac Newton, F.R.S. (1643–1727)

F.R.S. = Fellow of the Royal Society

René Descartes (1596-1650)

René Descartes, was a French mathematician, philosopher, and scientist. Dubbed the “Founder of Modern Philosophy” and the “Father of Modern Mathematics,” he ranks as one of the most important and influential thinkers of the Scientific Revolution.



Descartes' Philosophy:

What can we know for certain?

- We are constrained by the rules of logic.
- We can only have certain knowledge if there is no doubt that it is not true.
- To begin, can we trust our senses?
 - Can you believe what your eyes are telling you?

Problems with trusting our senses

- Perceptual Illusion
- The Dream Problem
- A Deceiving God



What do you know for certain?

Take a moment to think of one thing that is so true, you cannot even imagine it not being true.

(Remember, you can't trust your senses!)

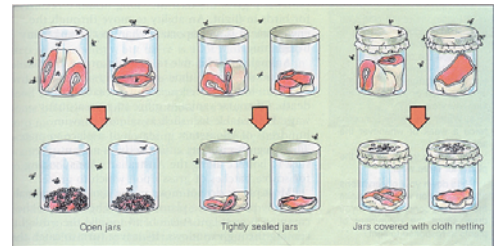
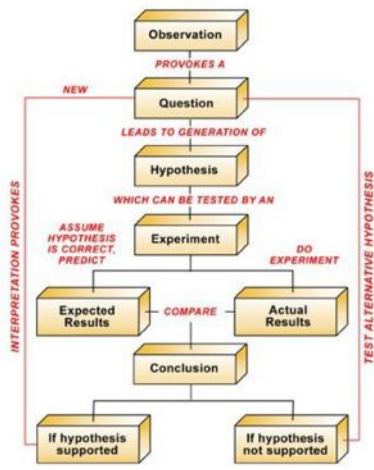
Cogito, ergo sum

"I think, therefore I am." is a philosophical statement by René Descartes in his *Principles of Philosophy* (1644), which became a foundational element of Western philosophy.

The Discourse on Method

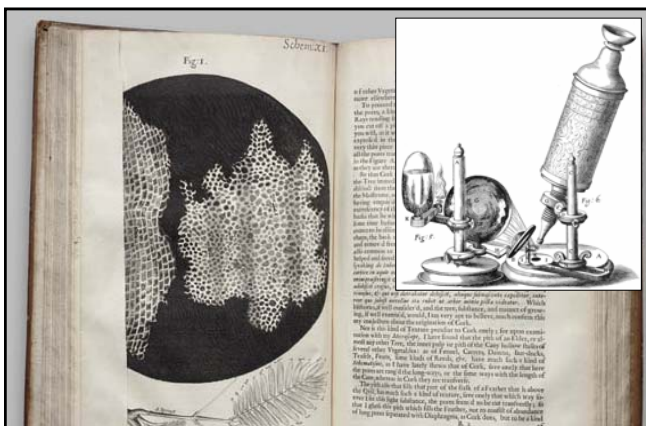
- The *Discourse on Method* is a philosophical and mathematical treatise published by René Descartes in 1637. Its full name is *Discourse on the Method of Rightly Conducting the Reason in the Search for Truth in the Sciences*.
- The *Discourse on Method* is best known as the source of the famous quotation, "Je pense, donc je suis."
- In addition, it contains Descartes' first introduction of the Cartesian coordinate system.

Frances Bacon and René Descartes are credited with the invention of the **scientific method**, but credit must also go to Alhazen, an Arab polymath who performed scientific optical experiments five hundred years before the Scientific Revolution.



In ancient times, people believed in spontaneous generation, that is, they believed that life could be generated from nonliving matter. In 1668, Francesco Redi disproved this theory with the following experiment.

People believed that rotten meat could turn into maggots because the maggots often appeared in decaying meat. The conclusion from Redi's experiment was that maggots appeared on the meat only if flies were able to enter the jars and lay eggs, thus disproving the hypothesis that maggots generated spontaneously.

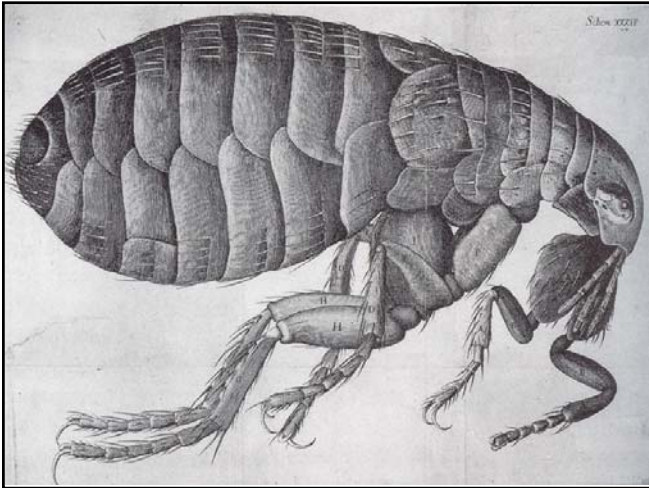


1655 Robert Hooke uses a compound microscope to describe small pores in sections of cork he calls "cells".

Micrographia is a book by Robert Hooke, detailing the then twenty-eight year-old Hooke's observations through various lenses. Published September, 1664, it was an immediate best-seller.

Hooke most famously describes a fly's eye and a plant cell (where he coined that term because plant cells, which are walled, reminded him of monks' chambers).

Although the book is most known for foregrounding the power of the microscope, *Micrographia* also describes distant planetary bodies, the wave theory of light, and various other philosophical and scientific interests of its author.

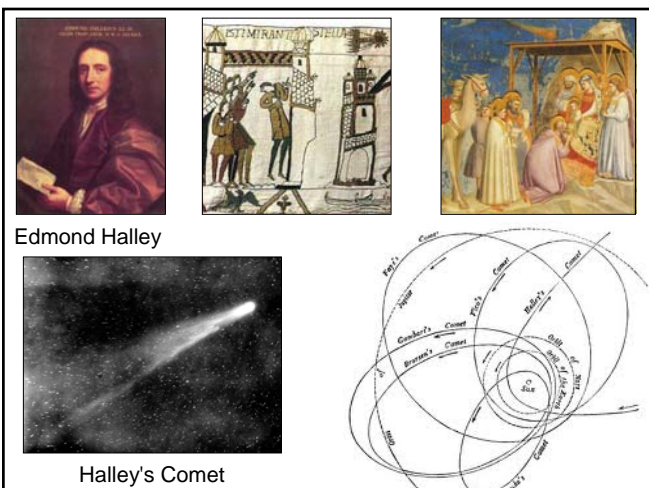
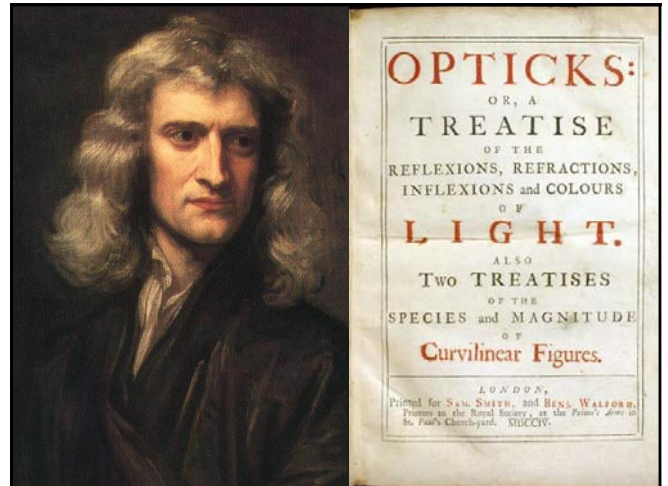
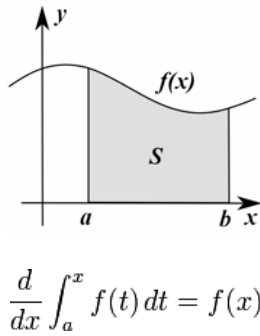
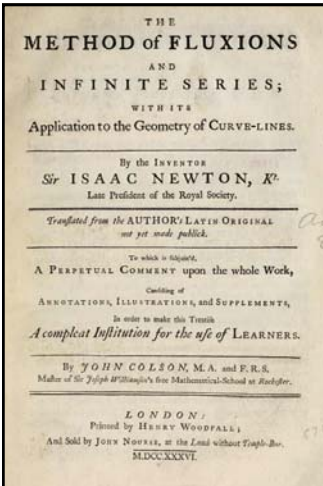


Isaac Newton (1643-1727)

"If I have seen further it is by standing on the shoulders of giants."

Sir Isaac Newton was an English physicist, mathematician, astronomer, alchemist, and natural philosopher, regarded by many as the greatest figure in the history of science.

He is most famous for inventing calculus and explaining gravity.



Edmond Halley

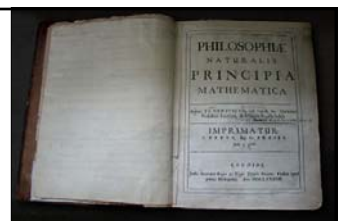


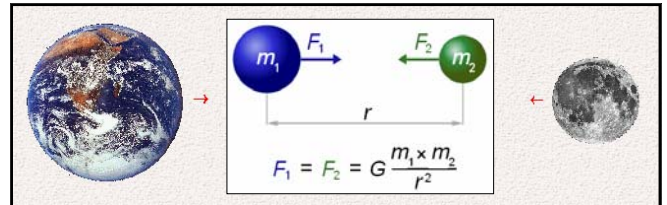
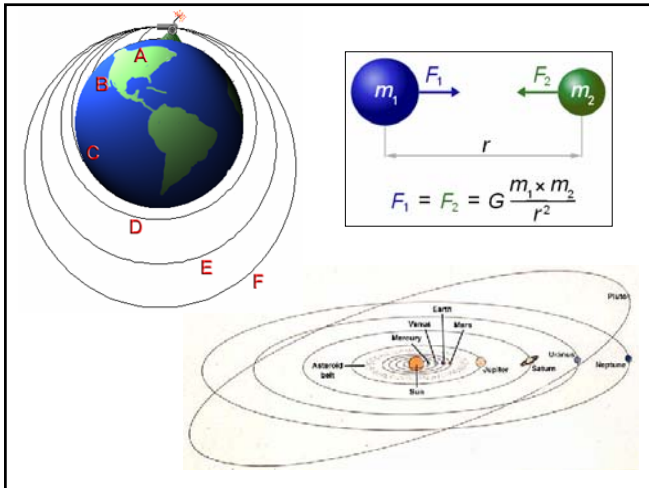
Halley's Comet

The Principia

Newton's treatise *Philosophiæ Naturalis Principia Mathematica*, published in 1687, described universal gravitation and the three laws of motion, laying the groundwork for classical mechanics.

By deriving Kepler's laws of planetary motion from this system, he was the first to show that the motion of objects on Earth and of celestial bodies are governed by the same set of natural laws.





- Clockwork Universe?
 - The universe can be thought of as a clock wound up by God at the beginning of time, ticking along like a perfect machine, with its workings governed by the laws of physics.
 - If we live in a 'clockwork universe', do we have free will? Or is everything predestined by the laws of physics?

Legacy of the Scientific Revolution

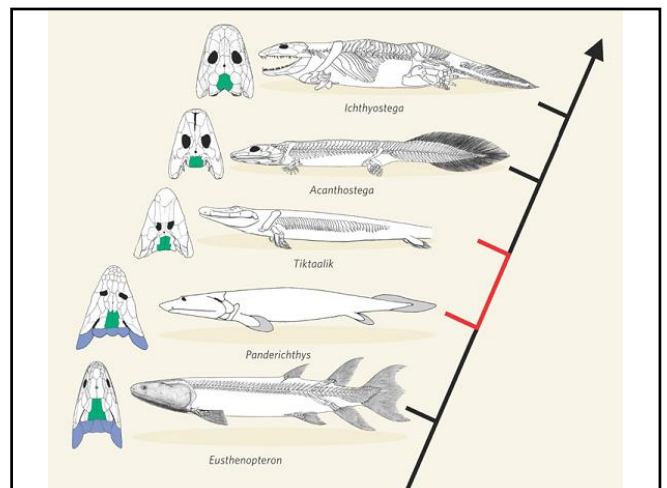
The Scientific Revolution caused a dramatic shift in the way people viewed themselves and their world. The Newtonian system became *the* accepted view of the universe (until superseded by quantum mechanics in the twentieth century).

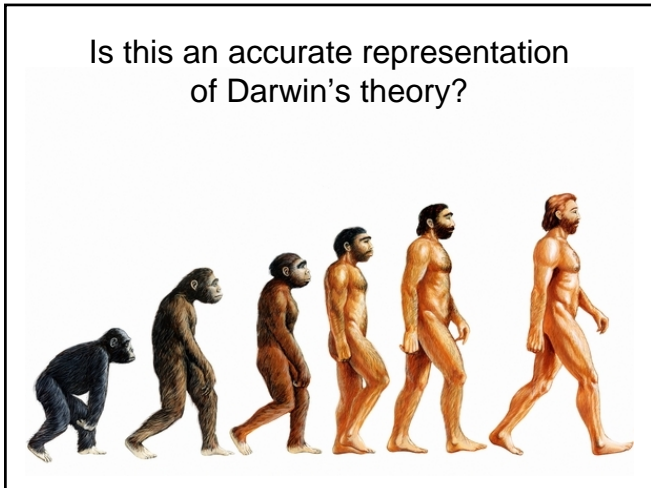
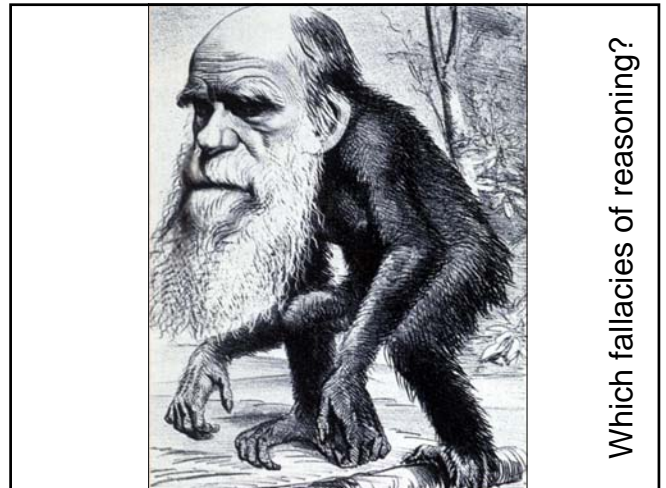
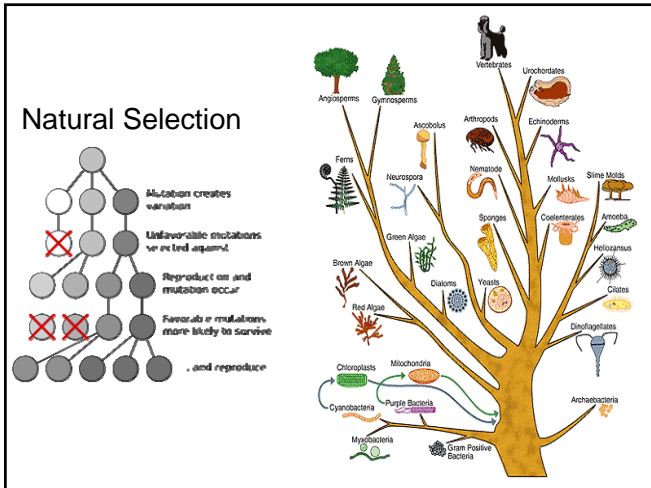
At the same time that science held out the promise that it could unlock the secrets of nature, it also contributed to an increase in skepticism. Everything was subject to systematic doubt, including religious beliefs, governments, and social mores. This intellectual restlessness is perhaps the most prominent feature of modern life.

Major Scientific Discoveries

- Evolution by Natural Selection (1859+)
- Plate Tectonics (1912+)
- Quantum Mechanics (1900+)
- The Big Bang (1931+)

In *On the Origin of Species* (1859), Charles Darwin provoked a storm of controversy by suggesting that all species of life had descended (evolved) from common ancestors. He proposed natural selection as the theory that would explain the process of change.





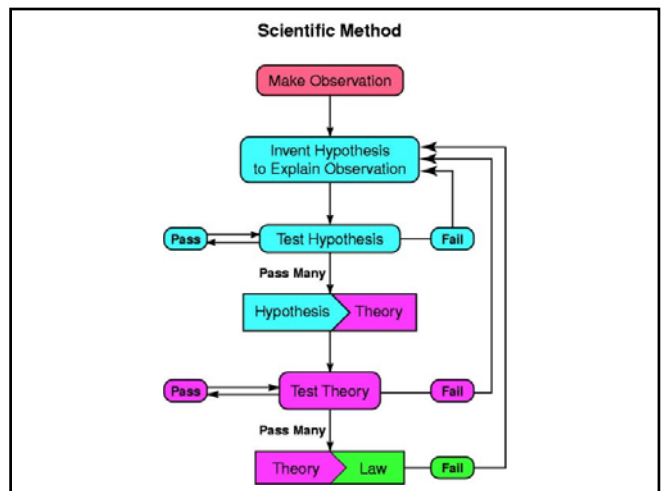
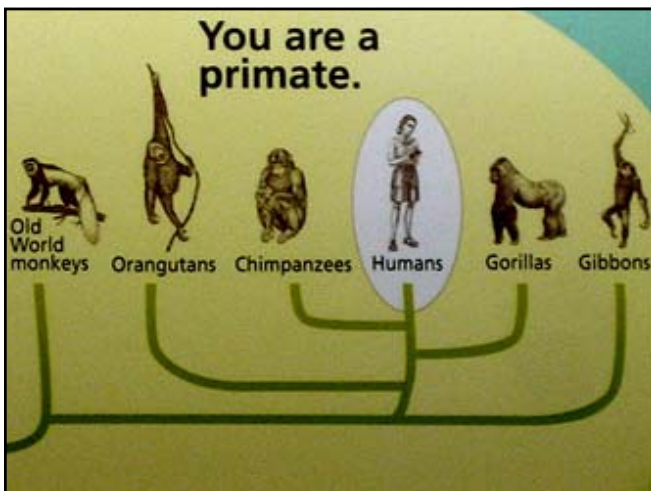
Common Misperceptions:

"Darwin says we came from apes."

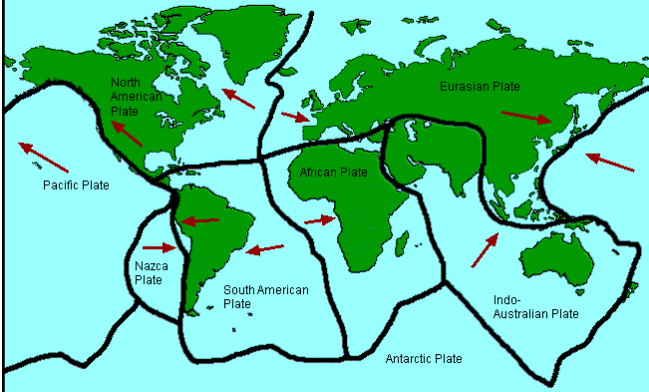
- This is not true. Darwin said we have a common ancestor from which both apes and humans both evolved.

"Evolution is 'just' a theory."

- This is not true. That plants and animals change (evolve) over time is a fact. Darwin's theory of natural selection provided the first reasonable explanation of why that change occurs. Evolution is accepted by an overwhelming majority of the scientific community.
- Also, saying evolution is "just a theory" is a straw man argument that confuses the terms "theory" and "hypothesis".



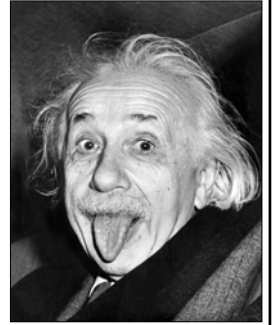
Continental Drift and Plate Tectonics



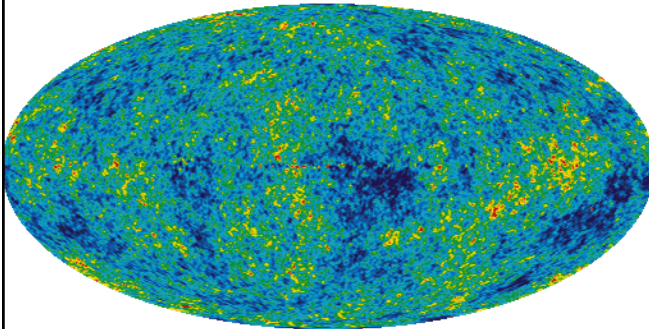
Quantum Mechanics

Albert Einstein (1879-1955) was a theoretical physicist who developed the theory of general relativity, effecting a revolution in physics.

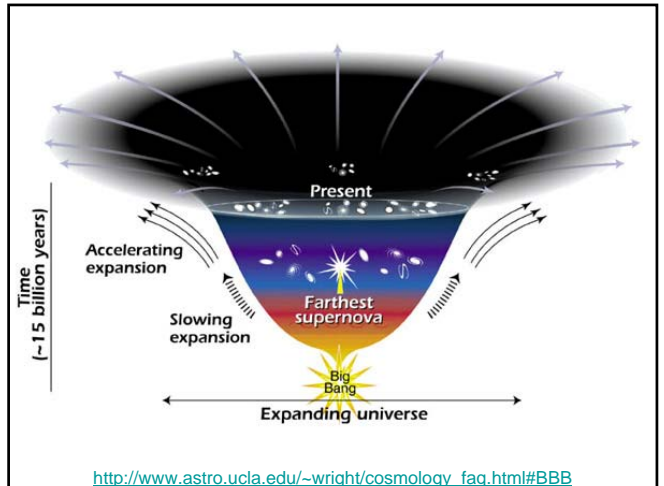
He received the 1921 Nobel Prize in Physics "for his services to theoretical physics, and especially for his discovery of the law of the photoelectric effect".



The Big Bang Theory



Cosmic microwave background radiation



Practice Questions

- Why do we call the time between Copernicus and Newton the "Scientific Revolution"? What changed?
- How do people decide what is true?
 - Consider the various cultures that we've studied, such as the ancient Egyptians, the Sophists, Socrates, Aristotle, and the Scholastics.
- How would the important scientific discoveries mentioned (such as evolution and plate tectonics) have affected peoples' worldviews, particularly with regard to God and religion?

