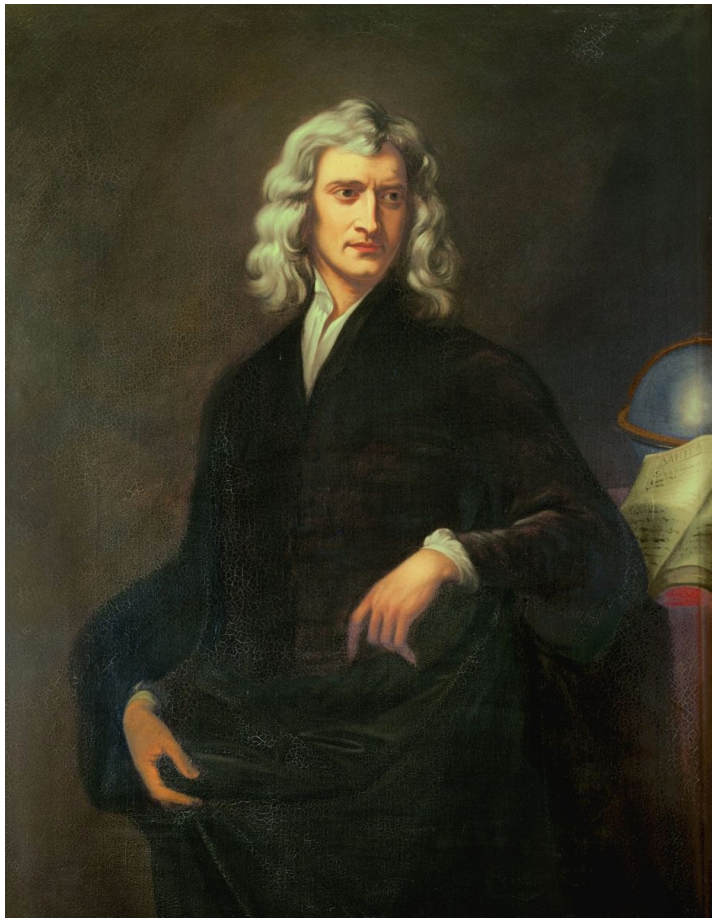
Lecture 4

Newton

GFN1000 In Dialogue with Nature

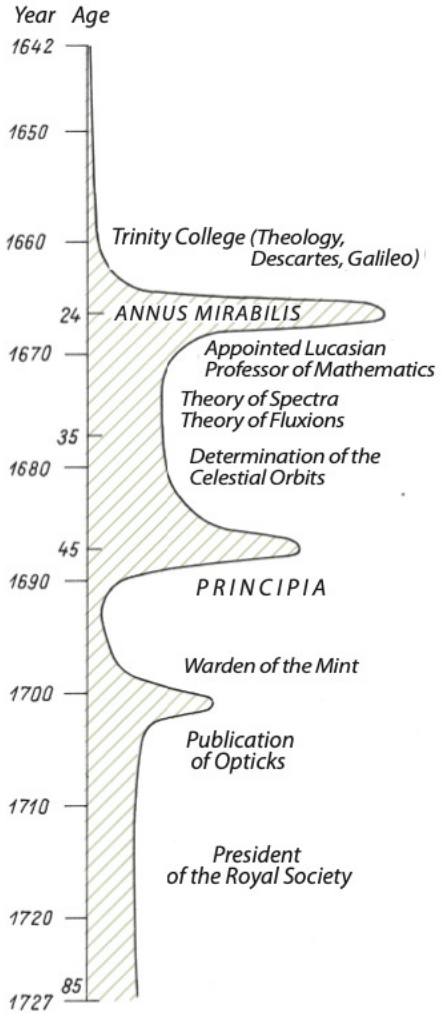
Content

- Newton the Person
- Scientific Revolution
  - Paradigm Shift
  - Standing on the Shoulders of Giants
  - Scientific Method
- Newtonian Physics
  - Force and Mechanics
  - Implications
- Science and Religion



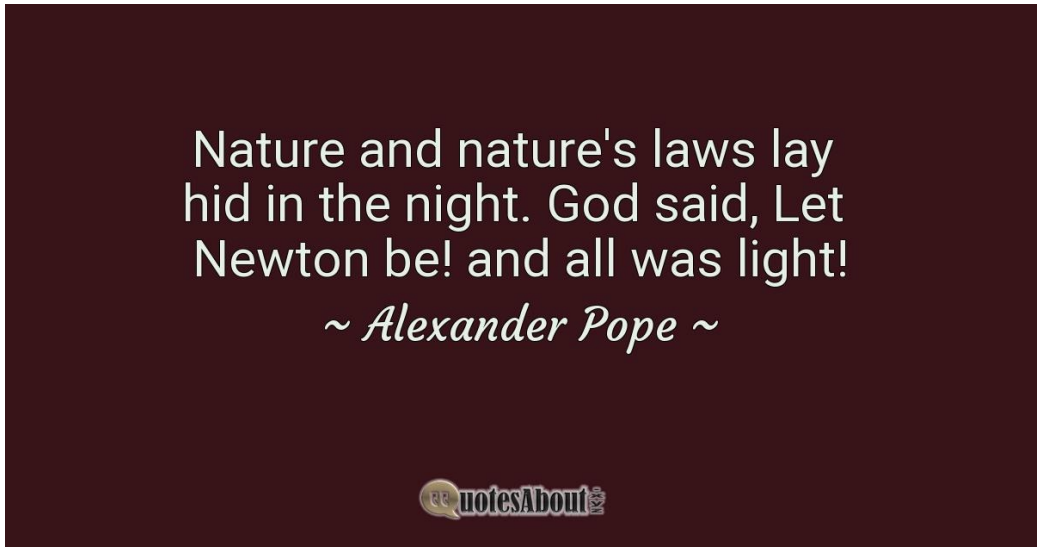
Isaac Newton (1642-1727)

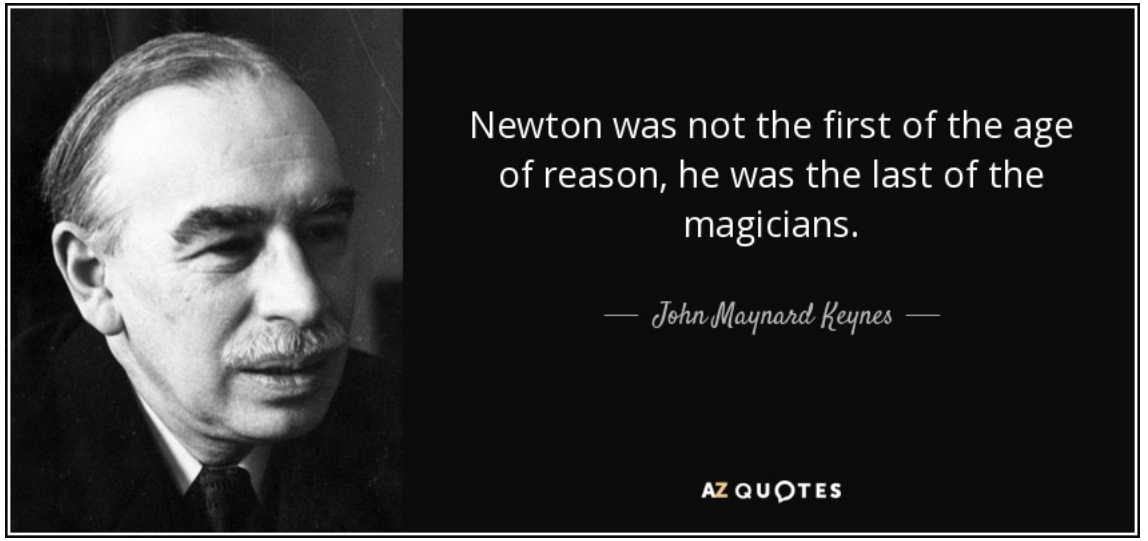
- English physicist, astronomer, mathematician
- Newton's private studies during the Great Plague (1666-1667)
- Elected Lucasian Professor of Mathematics at the age of 26 in 1669.
- Newton served as a Member of Parliament for the University of Cambridge, the Master of the Royal Mint (1700-1727), and the president of the Royal Society (1703-1727).



From Natural Philosophy to Science

- Physics/physique ← *physica* (natural philosophy)
- William Whewell coined the term "scientists" in 1833.

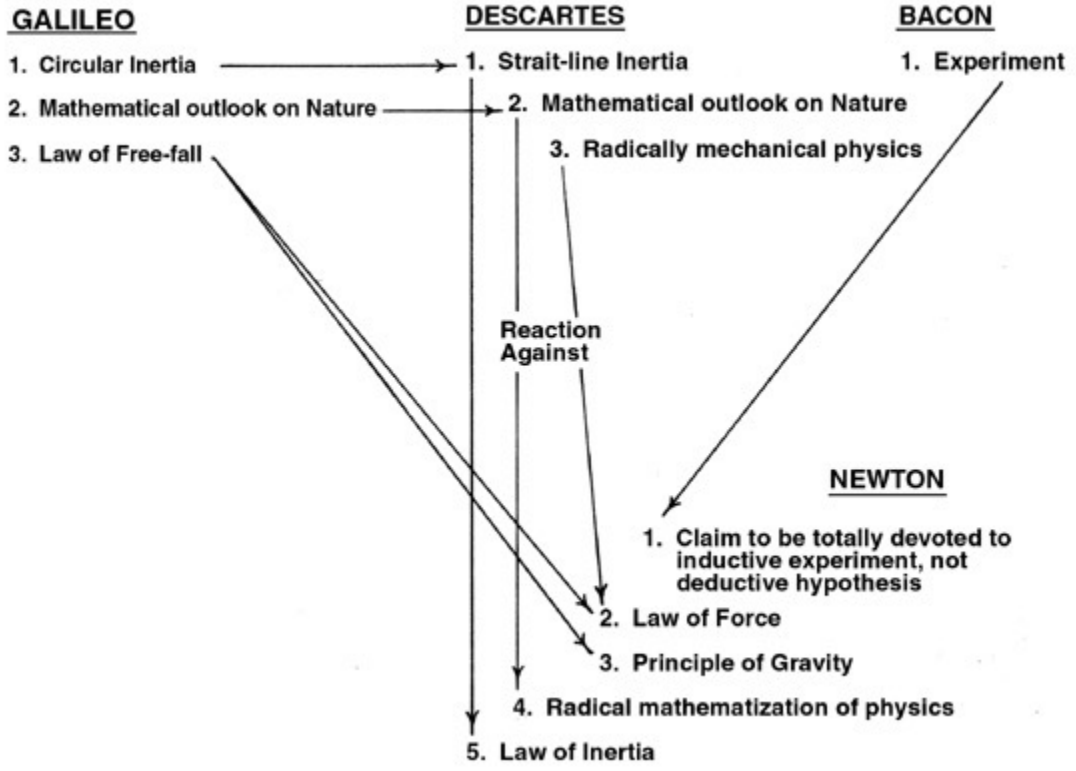




Shoulders of Giants

- Aristotle (384-322 BCE)
- Avicenna & Averroes (10-12th)
- Thomas Aquinas (1225–1274)

- Nicolaus Copernicus (1473–1543)
- Galileo Galilei (1564–1642)
- Johannes Kepler (1571–1630)
- Descartes (1596-1650)
- Newton (1642-1727)



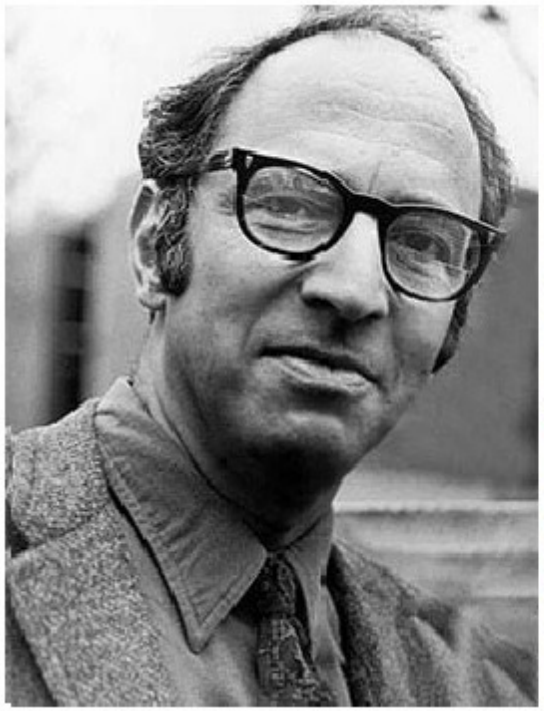
From Geocentrism to Heliocentrism

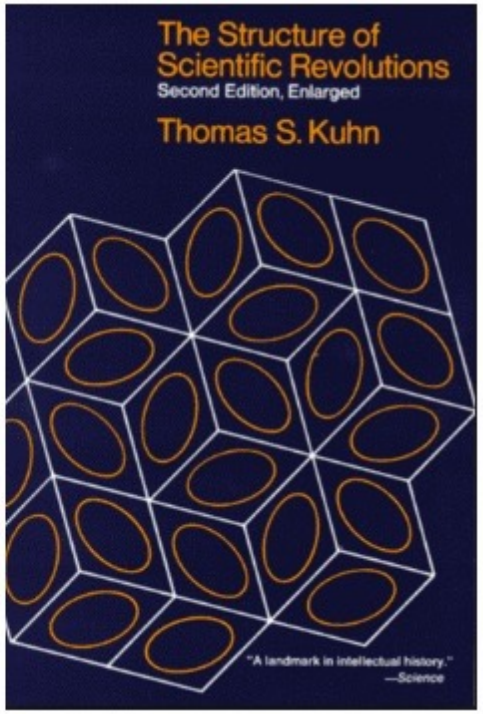
- Ptolemy (85-165) used mathematics to reconcile observation and Aristotelianism. His geocentric model employed devices including epicycles, deferents, and equants.
- Copernicus (1473-1543) was a Polish astronomer. His heliocentric model is characterized by mathematical elegance and simplicity.

Jan Matejko, Astronomer Copernicus

Paradigm Shifts

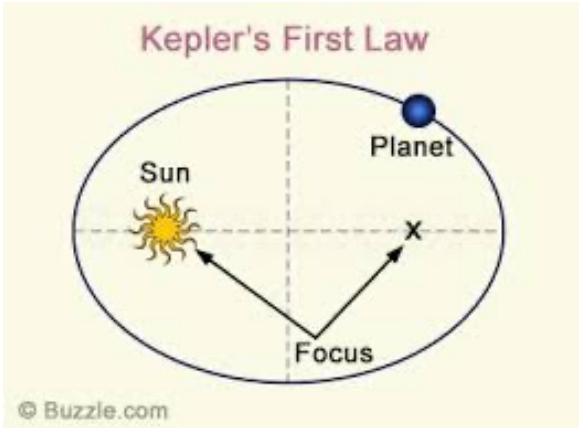
- Paradigm: **Universally recognized** scientific achievements that, for a time, provide model problems and solutions for a **community** of practitioners
  - Paradigms are **incommensurable**.
- Paradigm shift: a fundamental change in the basic **concepts** and experimental **practices** of a scientific discipline.

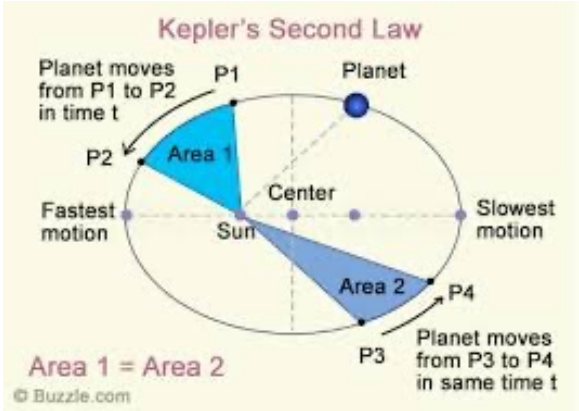




Johannes Kepler (1571-1630)

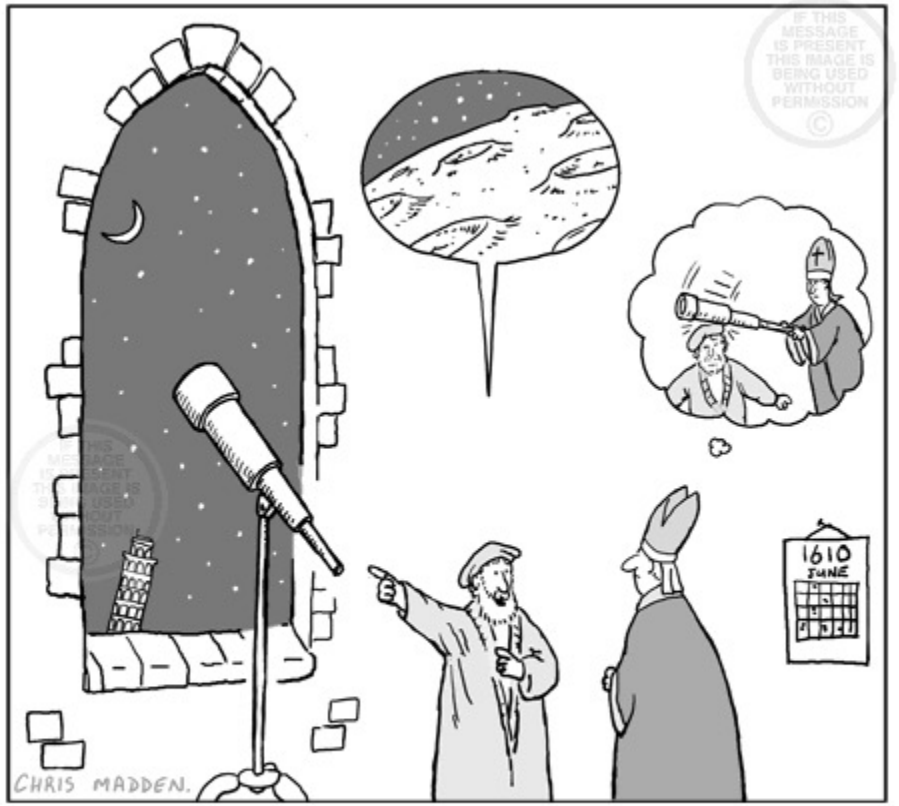
- German astronomer and astrologer
- Kepler’s laws of planetary motion
  - First Law: all planets move about the sun in **elliptical** orbits with the sun as one foci; against Aristotle’s claim that the motion is **circular**
  - Second Law: the radius vector joining any planet to the Sun sweeps out equal **areas** in equal **time**
  - Third law: The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.





Galileo Galilei (1564-1642)

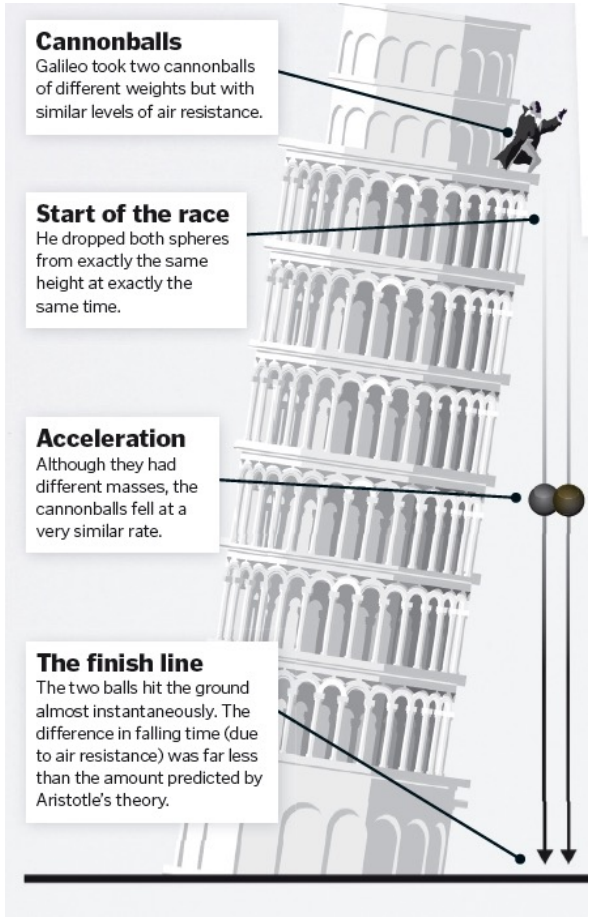
- Italian physicist and astronomer
- Galileo produced a telescope and used his telescopic observations to provide evidence in favor of Copernicanism
  - Mountains on the moon, sunspots, the rings of Saturn, the phases of Venus, and the satellites of Jupiter, etc.
- Galileo was accused of heresy and placed under house arrest.



GALILEO DESCRIBES HIS DISCOVERIES TO THE CHURCH

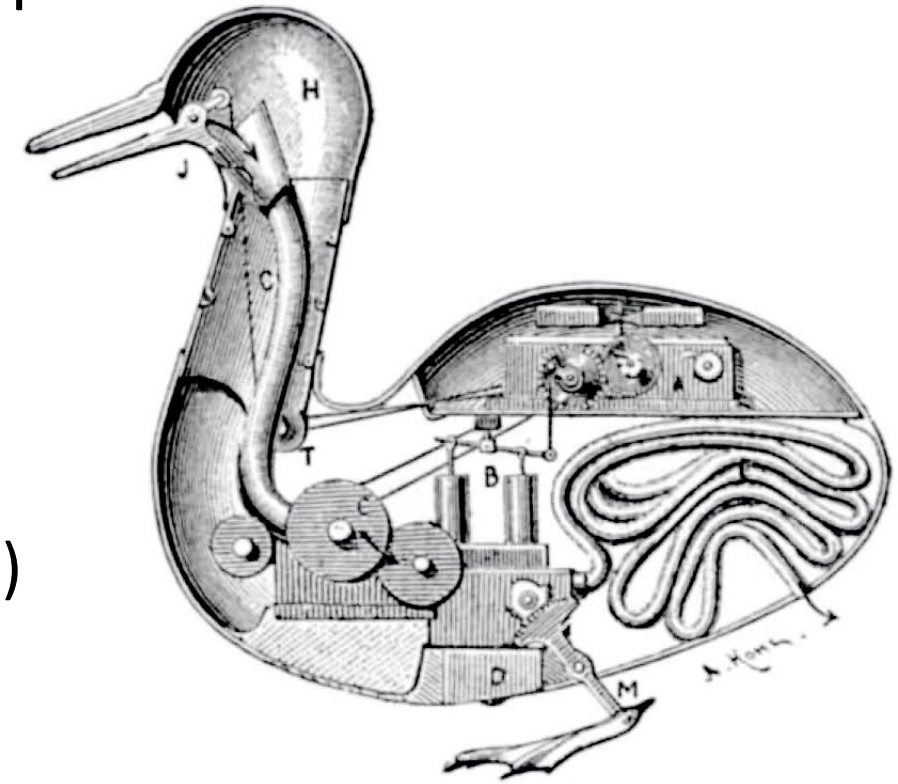
Galileo’s Experimental Investigation

- Galileo combined experiments, mathematics, and observation in his approach to natural philosophy.
  - "Father of modern physics" (Einstein)
- Galileo's Leaning Tower of Pisa experiment disproved Aristotle's theory.
- Galileo's Inclined Plane Experiment: velocity ∝ time elapsed, independent of mass.



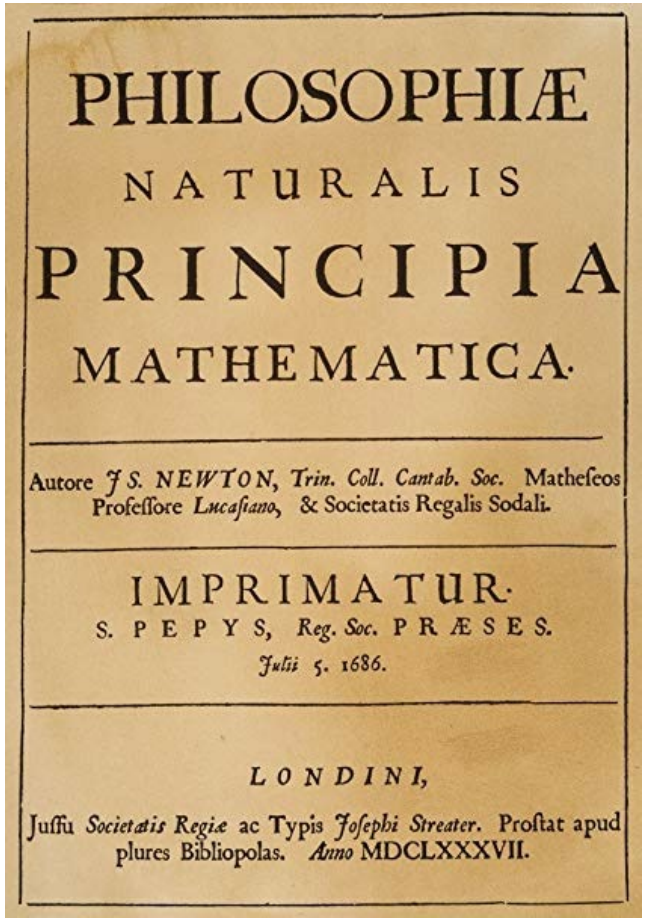
René Descartes (1596-1650)

- French philosopher and mathematician
- *Meditations on First Philosophy*
  - Knowledge must have a **secure foundation**.
- Mechanism vs. Aristotlelianism
  - Animals are merely mechanisms or automata (complex physical machines)
  - From the **ultimate good** to the **primary cause**



Newton and *Principia* (1687)

- *Mathematical Principles of Natural Philosophy*
  - Book 1 on the motion of bodies
  - Book 2 on mechanics of fluids
  - Book 3 on the planetary system
- Originally developed as a series of lectures at Cambridge.
- *Principia* provides the mathematical description of motion in the entire universe
- *Principia* makes Newton the founder of modern science


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

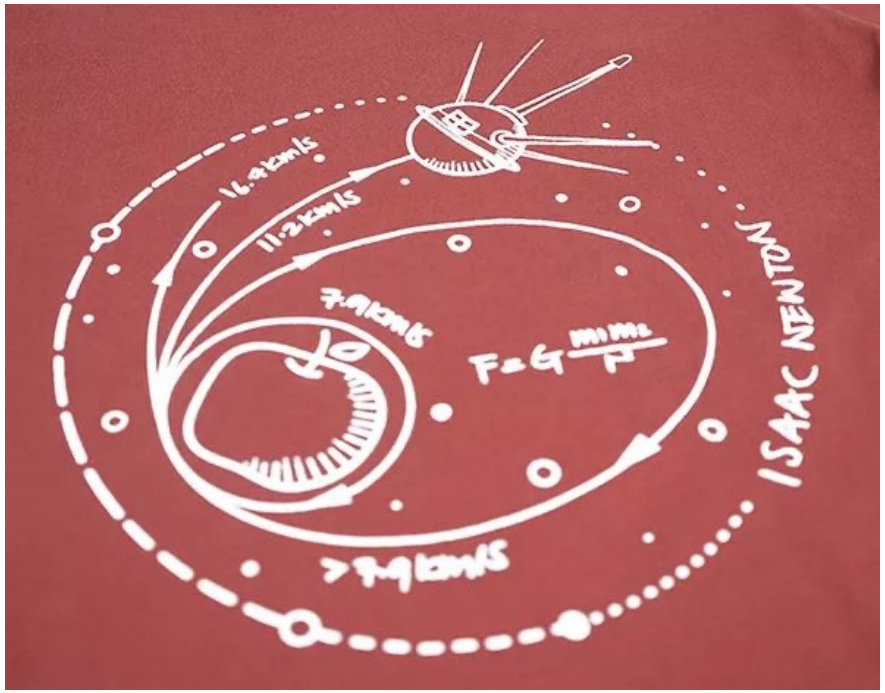
Autore *J S. NEWTON, Trin. Coll. Cantab. Soc.* Matheſeos Profeſſore *Lucaſiano,* & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Juſſu *Societatis Regiæ* ac Typis *Joſephi Streater.* Proſtat apud plures Bibliopolas. *Anno* MDCLXXXVII.

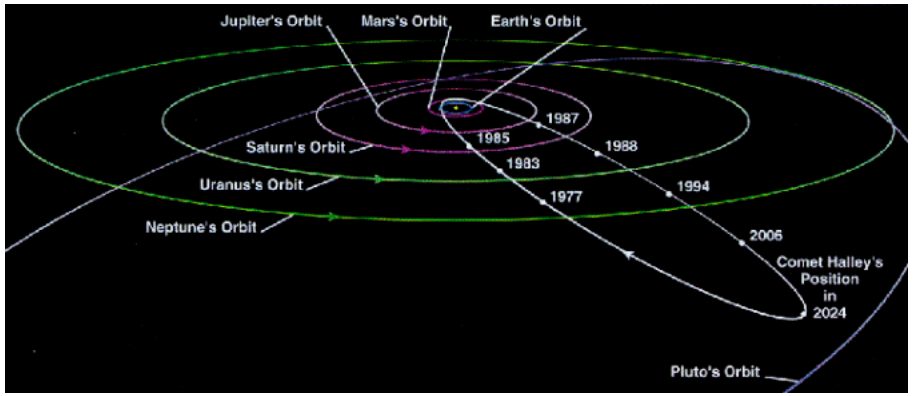
Force and Mechanics

- Newton conceives of force as a cause for change (acceleration).
  - Aristotle thinks that motion requires a constant force keeping the body to continue moving.
- Forces as **measurable** quantities
  - Thinking of forces as **quantities** that are proportional to other features of nature
  - **Abstract** characterization of forces
  - **Universal** gravity



Celestial Mechanics

- Centripetal force
- Using Newton's method, Edmond Halley (1656-1742) determined the period of Comet Halley in 1705 and correctly predicted the comet's return in 1758-1759 (16 years after his death).
  - Comet Halley returns every 76 years.
  - Last time: 1986. Next time: 2061.

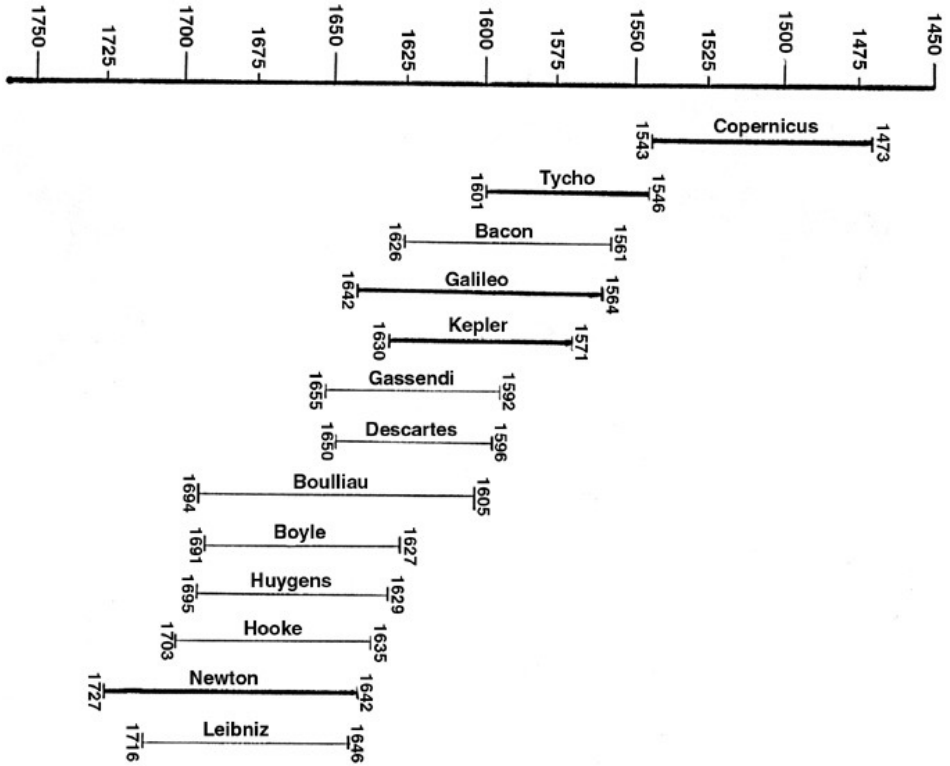


The Implications of Newtonian Physics

- **Mathematization** of nature
  - Quantitative descriptions and explanations
  - "Absolute, true, and mathematical" space and time
- **Universality**
  - Unified the terrestrial mechanics of Galileo and the law of celestial bodies of Kepler.

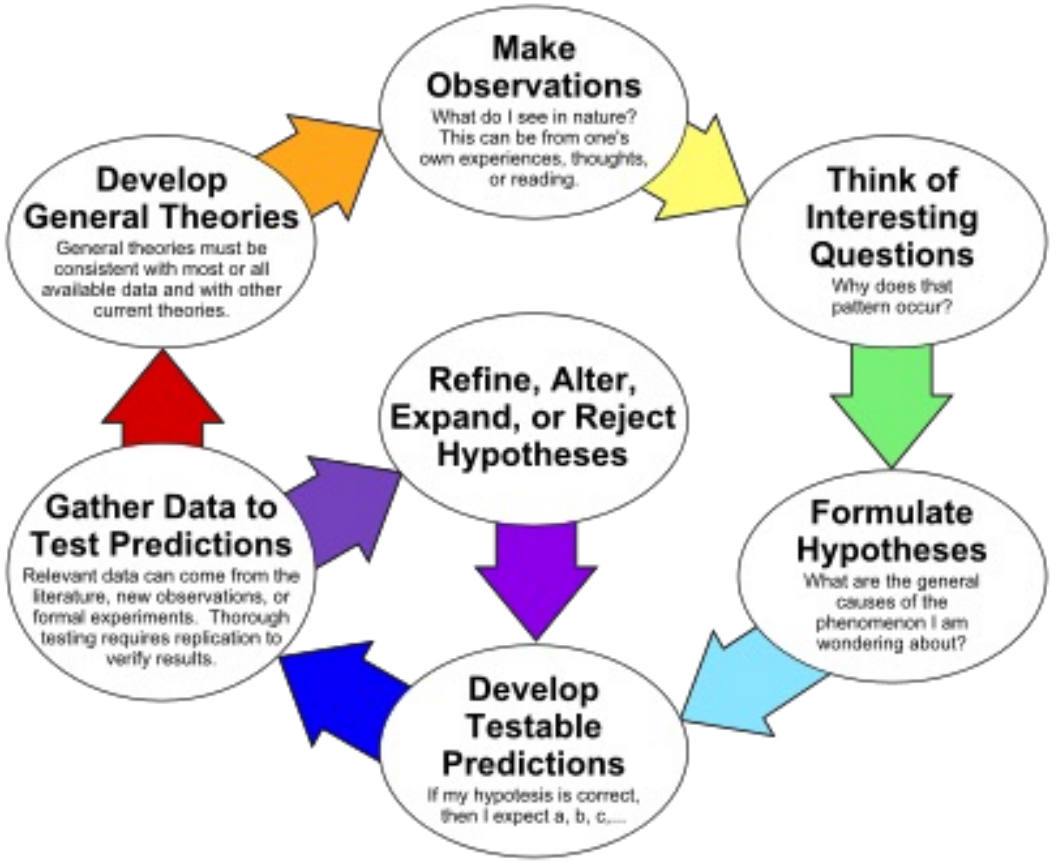
The Scientific Revolution

- Weaken and overthrow the stronghold of Aristotelian natural philosophy
  - A transformation from an **organic** worldview to a **mechanical** one
- People saw the promise that human **rationality** could eventually unlock nature's mysteries.
  - This faith in rationality resulted in the century of the Enlightenment.



Scientific Method

- Galileo: "Nature is written in the language of **mathematics**, and its characters are triangles, circles, and other geometric figures."
- Needham: "If I were asked to define modern science, I would say that it was the combination of mathematised hypotheses about natural phenomena with relentless **experimentation**."



Science and Religion: the Case of Newton

- Newton used testable hypotheses to find truth in nature and believed that his religious writings **revealed the truth about God**.
  - Newton's Biblical studies; interpretations of prophetical books of the Old Testament
- Pasteur: Man's first glance at the universe discovers only variety, diversity, multiplicity of phenomena. Let that glance be illuminated by science - by the **science which brings man closer to God** - and simplicity and unity shine on all sides.

Newton vs. Leibniz

- Newton: God of Workday
  - Clockwork universe: a world order maintained by immanent divine activity
- Leibniz: God of Sabbath
  - **Preestablished** harmony
  - "According to their (Newton and his followers) doctrine, God Almighty wants to wind up his watch from time to time."
- Koyré: "Every progress of Newtonian science brought new proofs for Leibniz's contention."