

## The Scientific Revolution

A revolution in human understanding and knowledge about the physical universe



## Ye olde periodic table

I <b>Er</b> Earth	More to not said	
II <b>Wa</b> Water	III <b>Ai</b> Air	IV <b>Fi</b> Fire
More to invention		

If you had gone to college and graduated in 1600 - You would have believed:

In witches, witchcraft and they can summon up storms  
 Werewolves  
 That Circe really did turn Odysseus crew into pigs  
 That Mice spontaneously generate from piles of straw  
 Magicians are real and You would have consulted one to find stolen goods  
 Unicorns and have seen one of their horns  
 That a murdered body would bleed in the presence of the murderer  
 In an ointment that if rubbed on a dagger which has caused a wound would heal the wound  
 That you can tell how a plant will work as medicine by its color, shape or texture, because God has designed nature to be interpreted by man



If you had gone to college and graduated in 1600 - You would have believed:

That base metal (lead) can be turned into gold  
 That rainbows are a sign from God and that Comets portend evil  
 Dreams predict the future  
 That the earth stands still and the sun and stars turn around it every 24 hours  
 Astrology is real, even though he does not know the exact time of his birth  
 Aristotle is the greatest philosopher (4<sup>th</sup> century)  
 Pliny (1<sup>st</sup> century), Galen and Ptolemy (2<sup>nd</sup> century) are the best authorities on natural history, medicine and astronomy  
 Jesuit Missionaries are performing miracles in foreign lands  
 And you own maybe a couple of dozen books



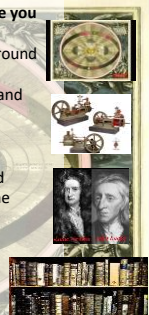
If you had graduated in the year 1733 from college you would :

Have looked through a telescope and a microscope  
 Own a pendulum clock and stick barometer  
 Not know anyone educated who believes in witches, werewolves, magic, alchemy, or astrology  
 Believe the Odyssey is Fiction, not fact  
 Believe that the shape or colour of a plant have NO significance for an understanding of it's medical use  
 Believe that no creature large enough to be seen by the human eye is generated spontaneously – not even a fly  
 Not believe in a weapon salve or bodies bleeding in the presence of a murderer



If you had graduated in the year 1733 from college you would :

Like all educated Protestants that the earth goes around the sun  
 Believe that a rainbow is caused by refracted light and that comets have NO significance for our lives  
 Believe the future could not be predicted  
 Have seen a steam engine work  
 Believe that science is going to transform the world  
 Have trouble believing in miracles – maybe even the ones in the Bible  
 Believe that Locke is the greatest philosopher and Newton is the greatest scientist  
 Own a couple of hundred, maybe even a thousand books



### Timeline of Discoveries in the Scientific Revolution

**1543** Copernicus discovers that the Earth revolves around the Sun.  
**1543** Vesalius discovers that blood circulates through the body due to the pumping of the heart.  
**1600** William Gilbert discovers that the earth is magnetic.  
**1620** Francis Bacon outlines a new system of logic based on inductive reasoning. This contributes to the development of the scientific method.  
**1610** Galileo Galilei discovers the moons of Jupiter, the phases of Venus, and the rings of Saturn. He also develops the laws of falling objects based on scientific observation.



Copernicus



Vesalius



Gilbert



Bacon



Galileo

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**1609** Johannes Kepler publishes the first two laws of planetary motion.

**1637** René Descartes helps to establish the scientific method.

**1660** Antonie van Leeuwenhoek builds a powerful microscope and observes microorganisms.

**Late 1600s** Sir Isaac Newton builds on the work of Kepler and Galileo.

Newton:

- Develops calculus
- Discovers the mathematical law of gravity
- Explains why planets have elliptical orbits
- Advances the law of universal gravitation.



Kepler

Descartes



Van Leeuwenhoek

Newton

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**1770s**  
 Mathematician Pierre-Simon Laplace develops Laplace's equation describing the behavior of electric, gravitational, and fluid potentials.



**1780s** Charles Augustin de Coulomb develops Coulomb's law explaining the electrostatic force of attraction and repulsion.



**1770s** Antoine Lavoisier, known as the "Father of Modern Chemistry," introduces the metric system.

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### Empiricism

Empiricism is a method of investigation involving the use of the senses.

It does not rely on ideas alone, but instead uses direct observation.

The scientific method is based on empirical testing of hypothesis and theory.

During the Enlightenment, empiricism was developed by John Locke, who said that the mind at birth was a "tabula rasa" (clean slate) which is written upon by experience.



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### René Descartes

René Descartes was a 16th-century French rationalist philosopher and mathematician.

Descartes believed that the senses alone were unreliable, and advocated the use of deductive reasoning.

He was a key figure in the scientific revolution.

His book *Discourse on Method* provided a method for scientific research.



Descartes and Queen Christina of Sweden

1. Accept only that of which you are sure
2. Divide your study into as many small parts as possible
3. Solve the simplest problems first
4. Make detailed lists of your work and results



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The scientific method is a systematic way to carry out research.

Use of the scientific method led to many great discoveries.

### Overview of the Scientific Method:

**Step 1** Make observations by searching for patterns.

**Step 2** Make a hypothesis by formulating general ideas based on observations.

**Step 3** Make predictions by stating what is expected based on the hypothesis.

**Step 4** Experiment to prove or disprove the hypothesis.



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In 1616, 60 years after its original publication, the church banned Copernicus' *De revolutionibus*, arguing that the idea of the Earth revolving around an immobile Sun was "false and altogether opposed to Holy Scripture."



Title page of *De revolutionibus*



The Astronomer Copernicus: Conversation with God by Jan Matejko

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The astronomer Galileo Galilei improved the telescope and supported the findings of Copernicus.

Galileo built an improved telescope to observe the stars and planets.

He observed that Jupiter had moons orbiting around it.

The discovery that moons could orbit another planet went against the Catholic Church's belief that all celestial bodies revolved around the Earth.

Galileo's direct observation gave support to the findings of Copernicus.



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Galileo's findings were so problematic for church doctrine that the Inquisition ordered him not to talk about them.

The Inquisition was introduced by the Catholic Church during the second half of the 16th century to prosecute individuals accused of a wide range of crimes related to heresy.



Galileo facing the Inquisition in 1616, by Cristiano Banti

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## SPIELVOGEL CHAPTER 16

### TOWARD A NEW HEAVEN AND A NEW EARTH: THE SCIENTIFIC REVOLUTION AND THE EMERGENCE OF MODERN SCIENCE



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# 1650-1720

These years saw the biggest advances in science since the Greeks.

## Why so long without advances?

There is a long gap between ancient scientists such as Aristotle, Galen, and Ptolemy and the Scientific Revolution (nearly 2,000 years).

## Why???



## Why so long without advances?

### 1. The Catholic Church

- The Classic View
- Not the only culprit



## Other Explanations:

2. Ancient Science was very advanced.
3. Printing Press
  - allowed scientists to communicate
4. Limited Mathematics
  - calculus was invented later
5. Limited technology
  - no telescopes, microscopes
6. Natural Science not emphasized in medieval universities
  - Church Controlled

# Copernicus & Galileo

*A Scientific Revolution*

Photo Credit: NASA

# COSMOLOGY

# Geocentrism

The belief that the earth is at the center of the Universe

Photo by NASA

## Reverence for Ancient Authorities

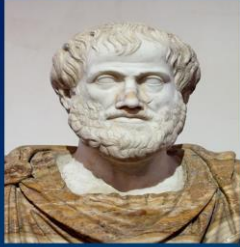


**Ptolemy**  
(2<sup>nd</sup> c. AD)

Greco-Egyptian  
mathematician  
& astronomer



## Reverence for Ancient Authorities



### Aristotle

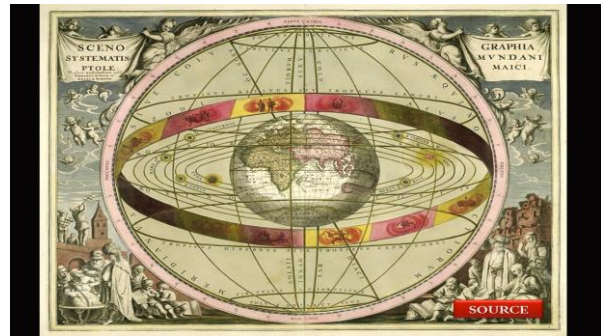
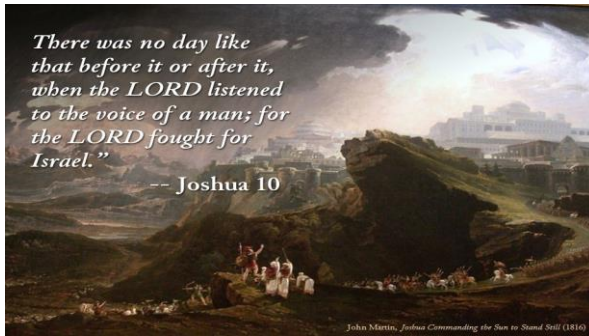
(4<sup>th</sup> c. BC)

Greek philosopher and scientist – THE authority on physics



*There was no day like that before it or after it, when the LORD listened to the voice of a man; for the LORD fought for Israel."*

-- Joshua 10



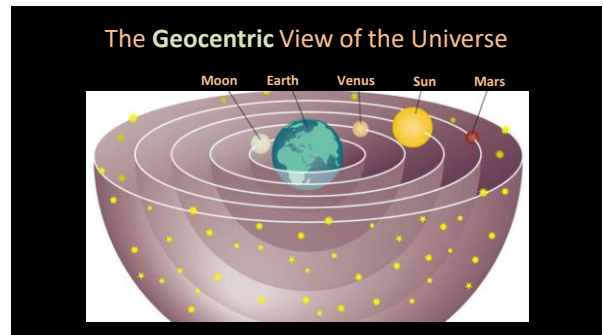
## Medieval "Science"

- Two bases fore knowledge: Bible and the ancients (Aristotle, Galen, etc.)
- Science follows scriptures, especially Old Testament (5<sup>th</sup>-16<sup>th</sup> Centuries)
- Scholasticism linked classical thinkers (Aristotle) to Christian faith

## The Medieval View

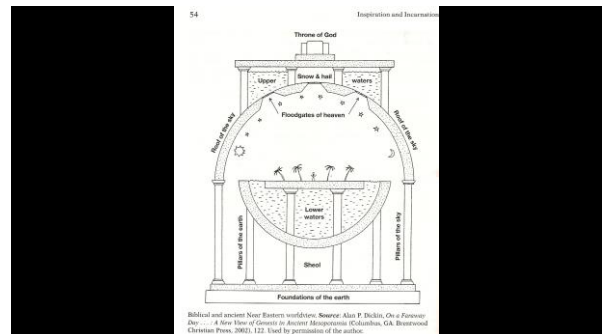
- Most knowledge in the Middle Ages comes from the Bible and Greek/Roman sources.
- Supports **geocentric theory**—moon, sun, planets revolve around earth





And of course there is always the Latest Theory  
Today!?

Crazy how nature does that



## THE MEDIEVAL VIEW OF THE COSMOS

□ A synthesis of

1. Aristotle
2. Ptolemy
3. Christian theology



## I. The Aristotelian Universe



- Derived from Ptolemy, Aristotle, and Plato
- Classical Writings "Christianized"
- Components of Medieval Cosmology
- Medieval Physics
- Belief in "Matter" and "Form"
- Earth = Living, Protected Sphere

## PTOLEMAIC/GEOCENTRIC CONCEPTION OF THE COSMOS

1. Earth centered
2. Series of 10 concentric spheres
3. Crystalline/transparent sphere
4. Perfect circular rotation
5. Heavenly bodies were orbs embedded in moving spheres
6. Beyond the 10<sup>th</sup> sphere = the kingdom of god/heaven
7. Man is at the center + god is in his place





## THE RENAISSANCE'S IMPACT ON THE SCI. REV.

- ❑ Renaissance Humanists – mastered Greek and Latin language  
-> Galen, Ptolemy, Archimedes, Plato, and pre-socratics
- ❑ Humanists discovered new ancient texts by Galen and Aristotle
- ❑ Renaissance artists impacted Sci. Rev. –
  1. observation of nature
  2. use of perspective and math in painting
  3. proper understanding of human anatomy



Scholasticism was a school of thought supported by medieval universities between 1100 and 1500. Scholasticism attempted to reconcile ancient classical (non-Christian) philosophy with the theology of the church.

 Scholasticism promoted learning by questioning, using dialectical reasoning.

 The goal of the questioning was to find answers to contradictions that existed between classical thought and church doctrine.



## MORE BACKGROUND FACTORS TO SCI. REV.

- ❑ Technical problems
- ❑ Emphasis on practical over theoretical knowledge
- ❑ Printing press -> spread ideas quickly and easily
- ❑ Mathematics – military sci., navigation, geography
- ❑ Leonardo da Vinci – nature is inherently mathematical and it provided certainty



## Superstition:

The Mother of Science

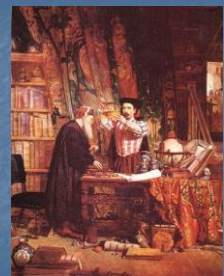
Alchemy



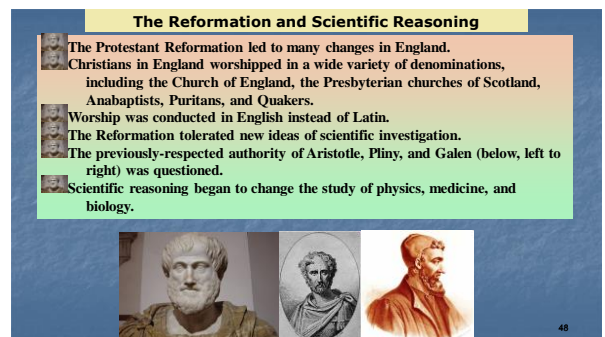
Chemistry

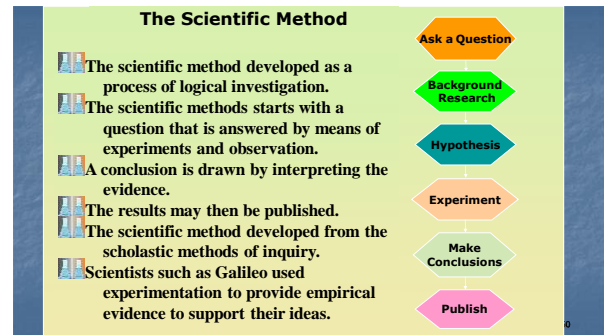
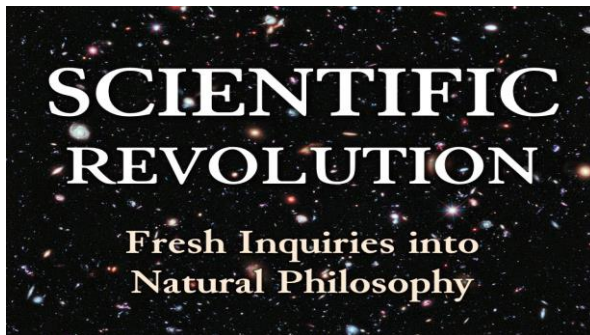
## Magic

- Hermetic magic = the world is divine, we are part of the divine -> we can tap in and control the world
- Alchemy = changing substances -> stuff into gold
- Astrology = position of stars-> influences our lives
- Numerology = numbers have secrets
- Use magic to control and dominate nature
- All giants of the sci. rev. studied magic





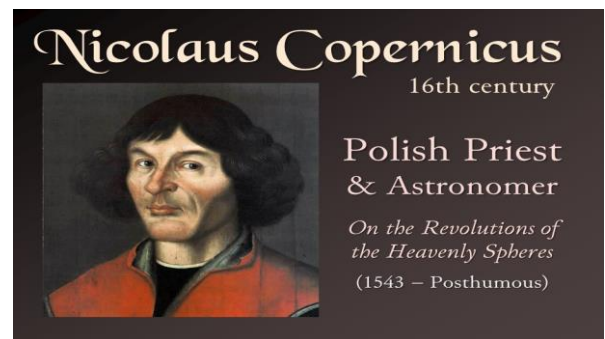


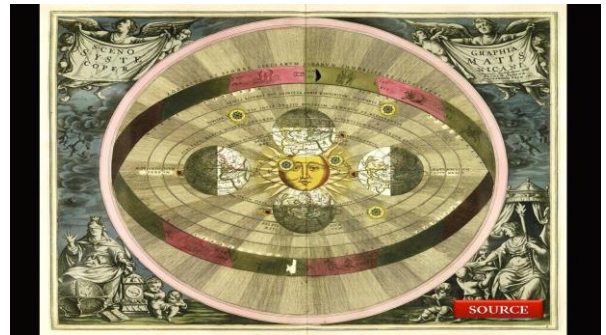
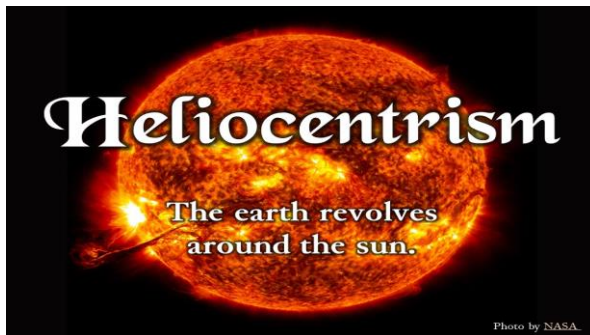


## II. Scientific "Revolutionaries"

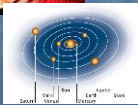
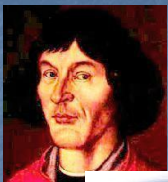
### A New Way of Thinking

- Renaissance prompts new ways of thinking (1300-1600)
- Scientific Revolution—new way of viewing the natural world—based on observation and inquiry
- New discoveries, overseas exploration open up thinking
- Scholars make new developments in astronomy and mathematics.





### A. Copernicus (1473-1543)

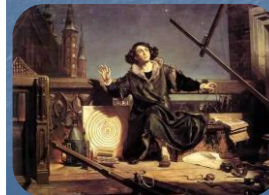


- Aim to glorify God
- Sun-centered universe
- Challenged circular orbits
- Universe of staggering size
- Earth no different than any other planet
- *On the Revolutions of the Heavenly Spheres* (1543) the starting point of modern astronomy
- Later scientists mathematically prove Copernicus to be correct

### Nicolaus Copernicus



Copernicus was a mathematician, astronomer, doctor, scholar, translator, minister, governor, military leader, and economist. Astronomy was merely an interest and a pastime, but it was his discovery in that field that made him one of the most influential people in world history.



Left: Painting by Jan Matejko  
Astronomer Copernicus:  
Conversation with God

1830 statue of Copernicus  
holding a sphere in front of  
the Academy of Sciences in  
Warsaw.



### B. Tycho Brahe (1546-1601)



- Most sophisticated observatory of his day
- Arrogant nobleman
- Remained an Aristotelian
- Discovered comet shooting right through crystalline spheres

### Brahe's Observatory







## TYCHO BRAHE 1546-1601

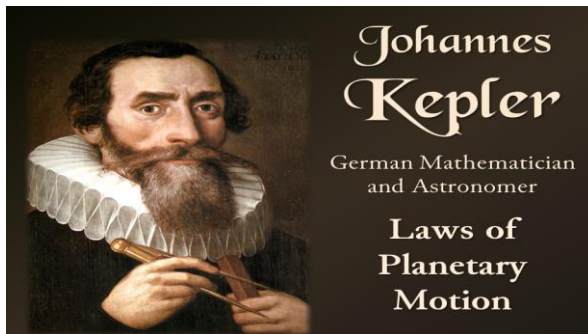


1. Danish nobleman/Danish Royal Astronomer
2. Builds Uraniborg Castle – library, observatories, instruments
3. Spends twenty years gathering data
4. Didn't have the maths ability to make sense of data
5. Moves to Prague -> becomes imperial mathematician to the Holy Roman Emperor



## BRAHE

While studying at University of Rostock in Germany, on 29 December 1566 Tycho lost part of his nose in a duel against fellow Danish nobleman Manderup Parsbjerg. Tycho had earlier quarreled with Parsbjerg at a wedding dance at professor Lucas Bachmeister's house on the 10th, and again on the 27th. The duel two days later (in the dark) resulted in Tycho losing the bridge of his nose. From this event Tycho became interested in medicine and alchemy. For the rest of his life, he was said to have worn a replacement made of silver and gold, using a paste to keep it attached. Some people, such as Fredric Ihren and Cecil Adams have suggested that the false nose also had copper. Ihren wrote that when Tycho's tomb was opened in 24 June 1901 green marks were found on his skull, suggesting copper. Cecil Adams also mentions a green colouring and that medical experts examined the remains. Some historians have speculated that he wore a number of different prosthetics for different occasions, noting that a copper nose would have been more comfortable and less heavy than a precious metal one.



## C. Johannes Kepler (1571-1630)



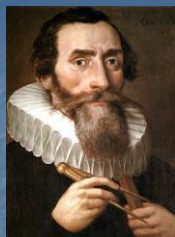
- Planetary motion conforms to mathematical formula
- Elliptical orbits
- Planets do not move at uniform speeds in their orbits

**Johannes Kepler (1571–1630)** was a German mathematician and astronomer.

- Kepler is most often remembered for his laws of planetary motion describing the orbit of two bodies when the mass of one is much smaller compared to the other, such as the Earth to the Sun.
- Kepler believed that God created the world according to an intelligible plan that can be explained through reason.



Kepler's Platonic solid model of the Solar System



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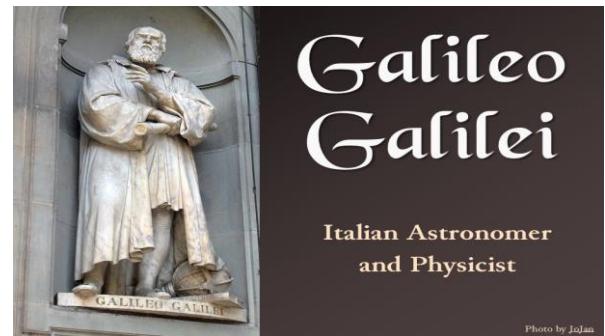
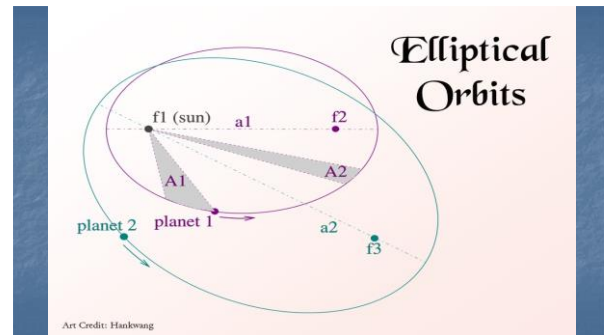
## JOHANNES KEPLER

1. Teacher of math and astronomy in Austria
2. Interested in astrology and hermetic mathematical magic
3. Brilliant mathematician and astronomer
4. Becomes Brahe's assistant
5. Succeeds Brahe as Imperial Mathematician
6. Uses Brahe's data to develop 3 laws of planetary motion



## KEPLER'S THREE LAWS OF PLANETARY MOTION

1. Elliptical orbits
  2. Speed of planets is greater when closer to sun
  3. Planets with larger mass revolve slower
- Kepler's laws destroy more elements of the Ptolemaic cosmos



### D. Galileo Galilei (1564-1642)



- Early practitioner of the experimental method
- Mathematical formula for acceleration of falling objects
- Law of inertia

### D. Galileo Galilei (1564-1642)



- Challenges categories of "form" and "matter"
- Heavens were no longer a spiritual world, but one of matter
- End of his life

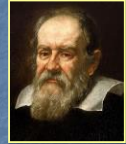
### Galileo Galilei

- Galileo is considered to be the father of physics, science, and astronomy.
- Galileo agreed with Copernicus that the earth was not the center of the universe.
- By Galileo's time, this idea was considered by the church to be very controversial. Galileo spent the last years of his life under house arrest for his beliefs.
- One of Galileo's contributions was the telescope. He improved the magnification of the telescope to 32 times, which was strong enough to explore the night sky.

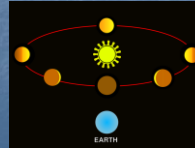


### Galileo Galilei

- With his telescope Galileo observed Venus, Jupiter, Saturn, Neptune, and the Milky Way.
- Galileo was one of the first to observe sunspots and to record mountains and craters on the moon and 4 moons around Jupiter



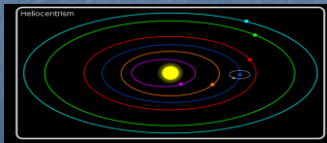
Galileo  
Galilei  
1564-1642



**Galileo Galilei (1564–1642)** made astronomical observations verifying the heliocentric (Sun-centered) view of the Universe proposed earlier by Copernicus.

- Galileo is considered one of the first pioneers of the scientific method because he used astronomical instruments to test his ideas.

- However, Galileo published his results using mathematical formulas and did not discuss his experiments.



## Aristotelian Physics

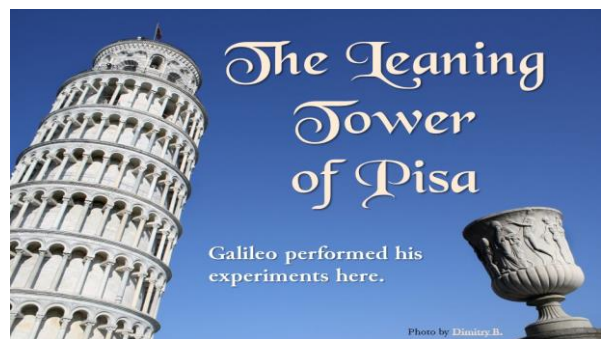
### Free Falling Objects

Heavy vs. Light Objects	Acceleration?
Heavy objects fall faster than lighter objects	Objects fall at a constant rate (no acceleration)
Logic	

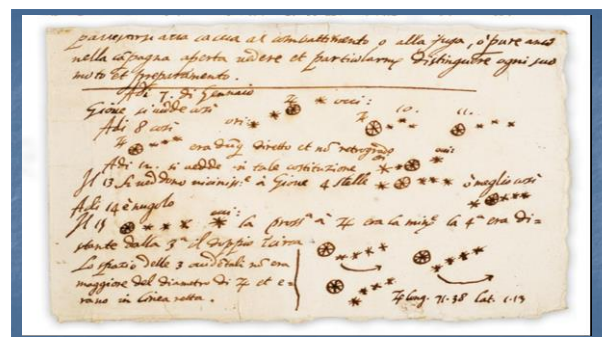
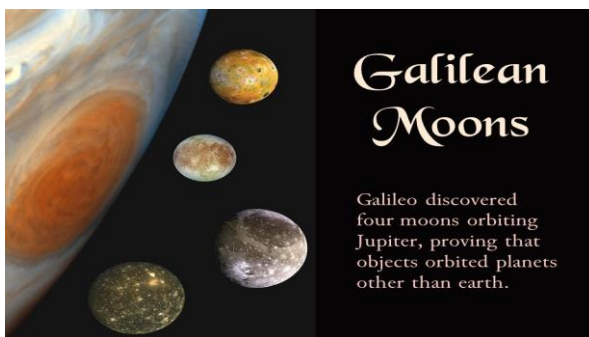
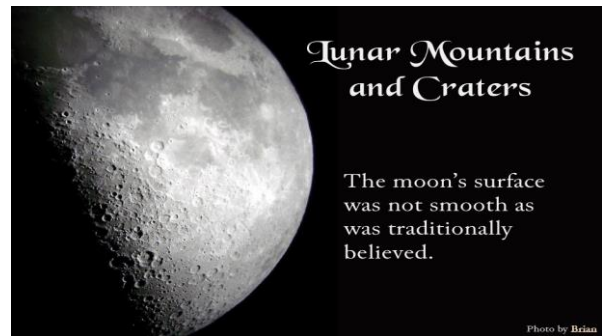
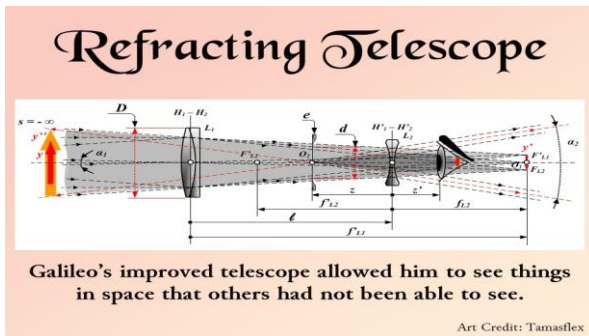
## Galilean Physics

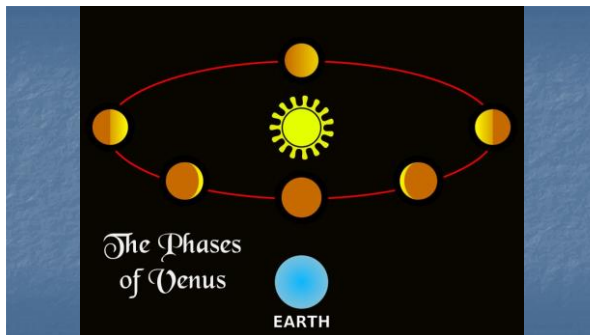
### Free Falling Objects


Heavy vs. Light Objects	Acceleration?
Heavy objects fall at the same rate as lighter objects	Objects accelerate as they fall due to gravity
Empiricism	





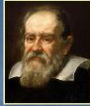




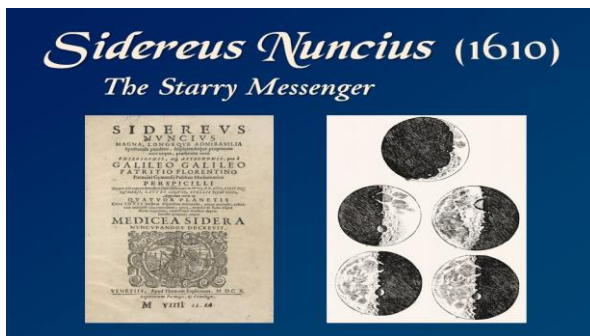


## GALILEO GALILEI

1564-1642




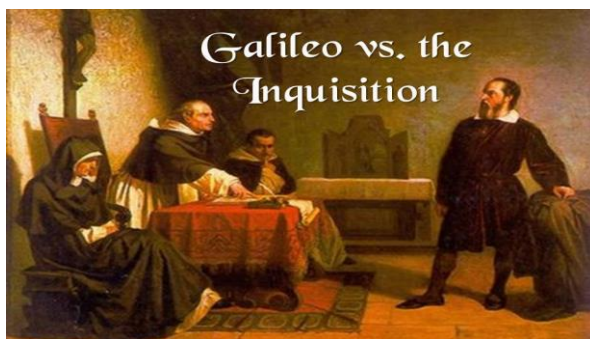
1. Italian mathematician and astronomer -> taught maths at Pisa and Padua
2. First to use telescope to observe the heavens
3. Uses telescope to see mountains and craters on moon, sunspots, moons of Jupiter
4. 1610 publishes *The Starry Messenger* -> advocated the heliocentric view
5. The Roman Inquisition/Holy Office of the Catholic church condemns Galileo's ideas and forces him to recant
6. Writes new book in Italian not latin -> more accessible/alarming to the church
7. Brought before the Inquisition again -> found guilty of error -> placed under house arrest for rest of life



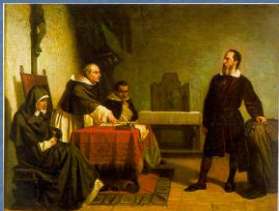
According to Stephen Hawking, "Galileo, perhaps more than any other single person, was responsible for the birth of modern science."

- Galileo works in mechanics/physics – the principle of inertia/uniform force causes an object to accelerate





## Conflict with the Church



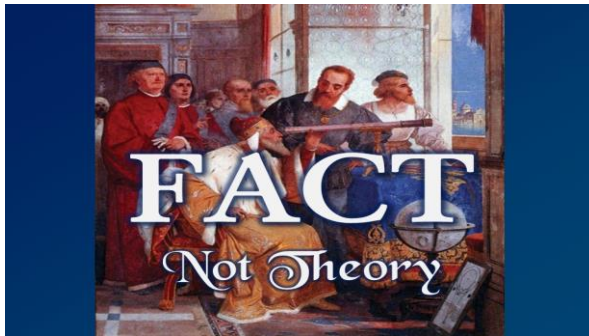
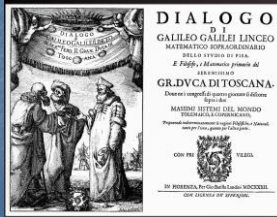
- Church attacks Galileo's work, fears it will weaken people's faith
- Pope forces Galileo to declare his and other new findings are wrong
- He was forced to recant his theories, and was placed under house arrest for the rest of his life.

Cristiano Banti's 1857 painting *Galileo facing the Roman Inquisition*

In 1615, the Catholic Church condemned the concept of heliocentrism.

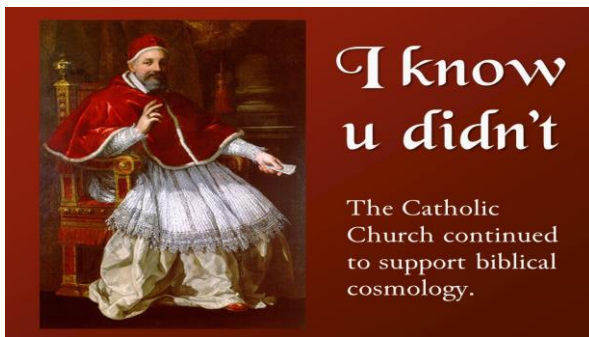
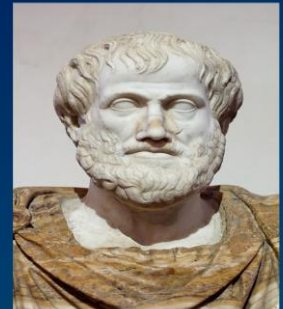
In 1616, Galileo was ordered to stop promoting his ideas about the Universe.

He was tried by the Inquisition after publishing in 1632 *Dialogue Concerning the Two Chief World Systems*.



I know  
u didn't

Aristotle believed that heavenly bodies were perfect spheres made up of the fifth element.

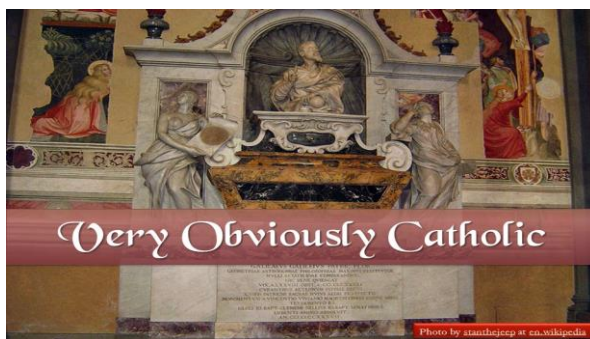






## Science vs. the Church?

Galileo recanted under pressure from the Church and remained under house arrest in his later years.



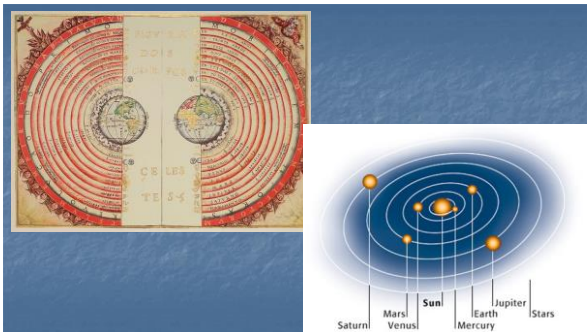
## Science vs. Religion?

"A little philosophy inclineth man's mind to atheism; but depth in philosophy bringeth men's minds about to religion."

-- Sir Francis Bacon



## Our Place in the Universe



## The Scientific Method

- A Logical Approach
  - Revolution in thinking leads to development of scientific method—a series of steps for forming and testing scientific theories
- Bacon and Descartes
  - Thinkers Bacon and Descartes help to create scientific method
  - Bacon urges scientists to experiment before drawing conclusions
  - Descartes advocates using logic and math to reason out basic truths

## Sir Francis Bacon

●1561-1626

●England

"A little philosophy inclineth man's mind to atheism; but depth in philosophy bringeth men's minds about to religion."





## E. Francis Bacon (1561-1626)



- Father of the Scientific Revolution
- The Inductive Method
- Emphasis on practical, useful knowledge
- New attitude toward nature

English scientist Francis Bacon made a major contribution to the scientific method with his publication of *Novum Organum* in 1620.

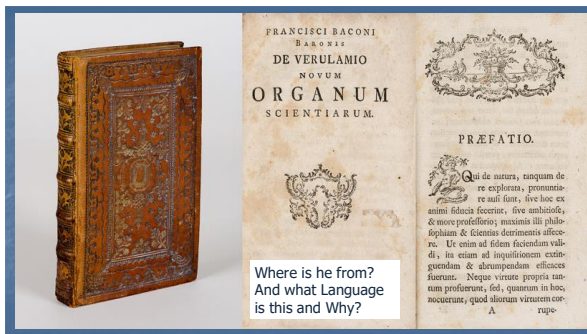
- His method of analysis used inductive reasoning.
- Bacon wrote of using empirical evidence from experimentation.
- Bacon's ideas were a response to the Aristotelian method of investigation based on absolute truths.

"Another form of induction must be devised than has hitherto been employed, and it must be used for proving and discovering not first principles (as they are called) only, but also the lesser axioms, and the middle, and indeed all. For the induction which proceeds by simple enumeration is childish."

Inductive reasoning: Reasoning from specific facts to general principles.



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Where is he from?  
And what Language  
is this and Why?

## Rene Descartes 1596 - 1650

- René Descartes was a 16th-century French rationalist philosopher and mathematician.
- Descartes believed that the senses alone were unreliable, and advocated the use of deductive reasoning.
- Cartesian Dualism



There is a Joke in here somewhere!?

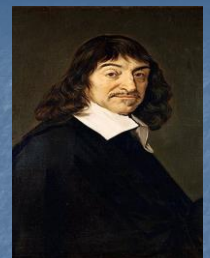
## G. Rene Descartes (1596-1650)



- Significance of Doubt
- The Deductive Method
- Spatial relationships can be expressed in mathematical formulas
- Father of "analytical geometry"

French philosopher René Descartes published a treatise titled *Discourse on Method* in 1637.

- He clearly defined the principles of the scientific method based on deductive reasoning.
- Descartes's method of reasoning led him to his most famous quotation, "*cogito ergo sum*," translated as "I think, therefore I am."



Deductive reasoning: Reasoning from general principles to specific cases.

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French philosopher **René Descartes** In 1647 Descartes wrote: "We must try to deduce from these principles knowledge of the things which depend on them, that there be nothing in the whole chain of deductions deriving from them that is not perfectly manifest."

4 Descartes believed that truth could be found through reason.

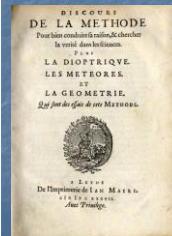
**Deductive reasoning:** Reasoning from general principles to specific cases.



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### René Descartes

His book *Discourse on Method* provided a method for scientific research.



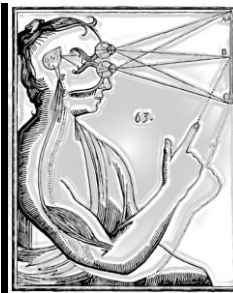
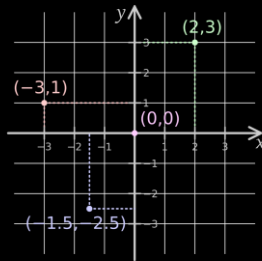
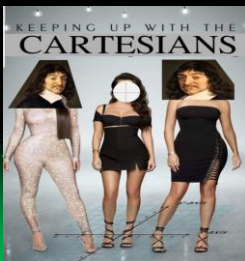
1. Accept only that of which you are sure
2. Divide your study into as many small parts as possible
3. Solve the simplest problems first
4. Make detailed lists of your work and results



Descartes and Queen Christina of Sweden

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## Cartesian Plane



René Descartes's illustration of dualism. Inputs are passed on by the sensory organs to the *gallivris* in the brain and from there to the immaterial spirit.

## Cartesian DUALISM

The mind and the body are separate.

### DUALISM

Cartesian Duality:  
MATTER-MIND



Physical and Mental substance is either fundamental or derivative.  
(solid line) (dashed line)

Credit: Dustin Dewynne

## Deductive vs. Inductive Reasoning



**DEDUCTIVE REASONING**  
Start with a premise  
Valid until disproven

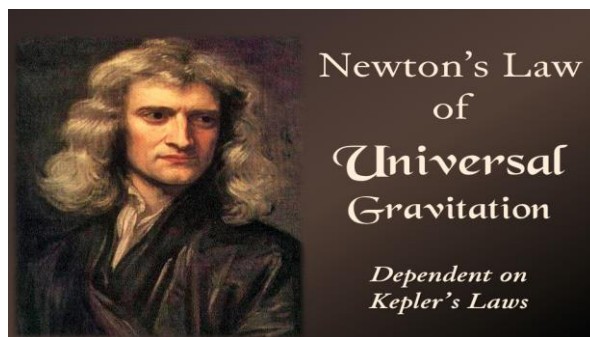
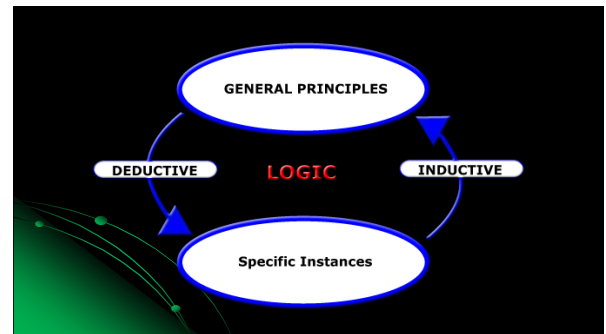
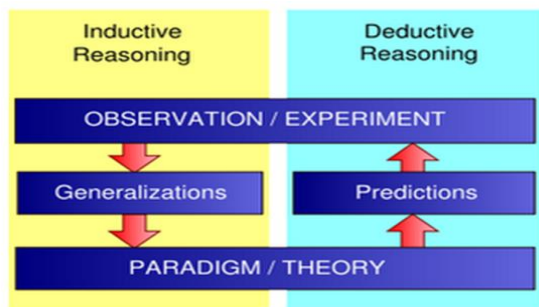
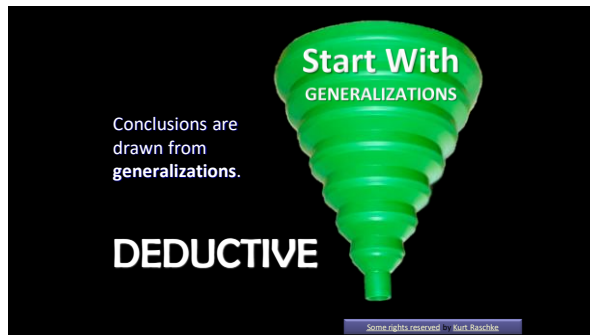


**INDUCTIVE REASONING**  
Start with observations  
Something must be **PROVEN** in order to be true


## Deductive Reasoning



- Premises
1. All men are mortal.
  2. Socrates is a man.
- Therefore,
- Conclusion
3. Socrates is mortal.



H. Isaac Newton (1642-1727)



- Newton far from the perfect rationalist
- A great synthesizer
- Blends inductive and deductive methods
- Argues for a universe governed by natural laws
  - views the universe as a vast, perfect mechanical clock
- *Principia; Mathematical Principles of Natural Philosophy* (1687)
- Law of Gravity

## Sir Isaac Newton

- 1643-1727
- Universal Gravitation
  - Dependent on heliocentric theory
- Laws of Motion
- Beginnings of Calculus



### Newton's Inductive Approach

Sir Isaac Newton (1643–1727) is best known for his discovery of the laws of gravity and motion. In his treatise titled *Principia*, Newton suggested four "rules of reasoning":

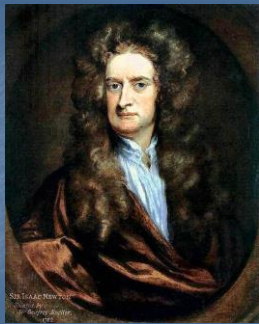
1. We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.
2. Therefore to the same natural effects we must, as far as possible, assign the same causes.
3. The qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.
4. In experimental philosophy we are to look upon propositions collected by general induction from phenomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phenomena occur, by which they may either be made more accurate, or liable to exceptions.



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### Sir Isaac Newton:

***"To explain all nature is too difficult a task for any one man or even for any one age. 'Tis much better to do a little with certainty, and leave the rest for others that come after you, than to explain all things."***



### Newton Explains the Law of Gravity

- Newton's Theories (continued)
  - Motion in space and earth linked by the law of universal gravitation—holds that every object is universe attracts every other object
  - Newton views the universe as a vast, perfect mechanical clock



Isaac Newton in 1702

## SIR ISAAC NEWTON – THE GREATEST FIGURE OF THE SCIENTIFIC REVOLUTION

1. Professor of mathematics at Cambridge University
2. Invented the calculus = advanced math
3. Published the *Principia* = The Mathematical Principles of Natural Philosophy
  - a. the three laws of motion
  - b. applies terrestrial laws to planetary bodies
  - c. Universal Law of Gravitation = could explain all motion in the universe



## THE NEWTONIAN SYNTHESIS

The combination of the new science + astronomy + mechanics + advanced math/calculus =

the universe was a regulated and uniform machine that operated according to natural laws





**Isaac Newton was a physicist, mathematician, astronomer, alchemist, and philosopher.**

■ Using intensive experimental methods, Newton discovered the three laws of motion and the universal law of gravitation.

■ Newton's work is considered the backbone of modern mechanics.



Newton's 6" reflector telescope



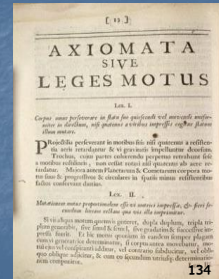
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**Newton's three laws of motion are the foundation of modern physics.**

**Newton's 1<sup>st</sup> Law:** An object at rest remains at rest. An object in motion remains in motion. Motion does not change until a force is applied to the object.

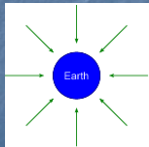
**Newton's 2<sup>nd</sup> Law:** The change in momentum of an object is due to the force applied to that object.

**Newton's 3<sup>rd</sup> Law:** For every action there is an equal and opposite reaction.

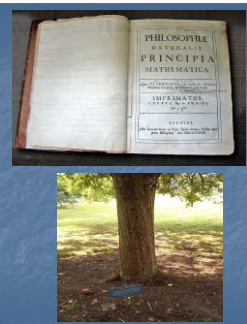


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**Newton's discovery of the universal law of gravitation was said to have been inspired by an apple falling from an apple tree.**



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## Newton

- Made president of the Royal Society
- Knighted in 1705 for achievements
- Only English scientist to be buried in Westminster Abbey

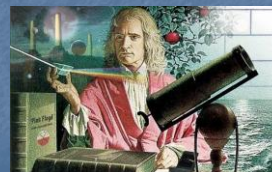


Sir Isaac Newton

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## Newton and the Occult


- Although a distinguished modern scientist, Newton had interest in the occult




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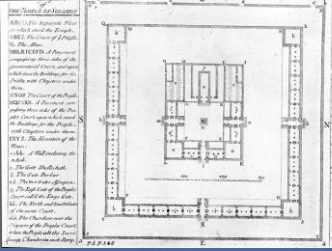
## Sacred Geometry




Knights Templar



Freemasonry





NEWTON

## Newton and the Occult

- Left behind hundreds of manuscripts on his study of alchemy
- He repressed publication due to psychological and political reasons
- Representative of the Hermetic tradition



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## Newton and the Occult

- Newton's Occult research thought to involve
  - Cosmology
  - Elements (alchemy)
  - Papers and traditions handed down through the ages from the time Babylonia



Newton, Warden of  
Royal Mint

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## Index Librorum Prohibitorum

- The *Index Librorum Prohibitorum* ("List of Prohibited Books") was a list of works prohibited by the Roman Catholic Church.
- Authors who appeared on the list could defend their writings, edit them, or censor their work.
- The index was first published in the 1500s and regularly updated until 1948.



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## Notable Authors on the List of Prohibited Books:

Francis Bacon  
Honoré de Balzac  
George Berkeley  
Giacomo Casanova  
Auguste Comte  
Nicolaus Copernicus  
Daniel Defoe  
René Descartes  
Denis Diderot  
Gustave Flaubert  
Frederick II of Prussia  
Galileo Galilei  
Thomas Hobbes  
Victor Hugo  
David Hume

Immanuel Kant  
John Locke  
Martin Luther  
Niccolò Machiavelli  
Maimonides  
Charles de Secondat, Baron de Montesquieu  
Blaise Pascal  
Samuel Richardson  
Jean-Jacques Rousseau  
George Sand  
Baruch de Spinoza  
Voltaire  
Émile Zola

## III. Causes of the Scientific Revolution



- Medieval Intellectual Life and Medieval Universities
- The Italian Renaissance
- Renewed emphasis on mathematics
- Renaissance system of patronage
- Navigational problems of long sea voyages
- Better scientific instruments

### III. Causes of the Scientific Revolution (Continued)



- Printing press -> spread ideas quickly and easily
- Printing press -> spread ideas quickly and easily
- Renaissance artists impacted Sci. Rev. –
  - observation of nature
  - use of perspective and math in painting
  - proper understanding of human anatomy

### IV. Consequences of the Scientific Revolution



- Rise of the "Scientific Community"
  - Royal Society of London (1662)
  - Academy of Royal Sciences (1666)
- The modern scientific method
- A universe ordered according to natural laws

## Royal Academies

The Scientific Revolution was aided by the development of *Royal Academies* in the seventeenth century.

Established by absolute monarchs for Scientific Investigation

**Why?**

## Royal Academies



### Better Science = Better Warmaking

Also, Alchemy could make a king rich (for those who believed in it)

Royal Academies published *journals* so that scientists could communicate.

Others could continue their experiments. (e.g., Copernicus → Galileo)

### Louis XIV at the French Academy of Sciences



### The Royal Society

The Invisible College was organized in the mid-17th century by a group of twelve natural philosophers who would meet to exchange scientific ideas.

From this group emerged *The Royal Society of London for the Improvement of Natural Knowledge*.

The Royal Society was formally chartered in 1662, with King Charles II formally taking credit for its foundation in 1663.

The Royal Society dedicated itself to promoting the uncensored flow of information between scientists throughout Europe.

#### Invisible College



Charles II being presented with a pineapple grown in England



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## The Scientific Revolution Spreads



microscope



thermometer



mercury barometer

- Scientific Instruments
  - Scientists develop microscope, barometer, and thermometer
  - New instruments lead to better observations and new discoveries

## New Invention: The Telescope

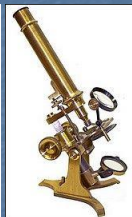


Illustration of Galileo at his telescope

- Invented in the Netherlands
- Galileo
- Newton

## New Invention: The Microscope

- Hans Janssen
- Anton Van Leeuwenhoek
- Robert Hooke

Hooke's drawing of a flea (from *Micrographia*)

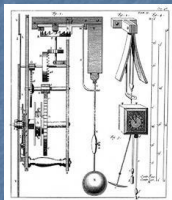
A Janssen microscope, c.1600

## Anton Van Leeuwenhoek

- Leeuwenhoek (Dutch--
  - Used the new microscope to see blood corpuscles, sperm, bacteria
  - Published drawings; no one took bacteria seriously as cause of disease, though



## New Invention: The Pendulum Clock



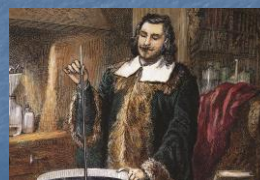
Huygens's design for a pendulum clock

- Invented by Christiaan Huygens, a 17th-century Dutch scientist
- Allowed scientists to more accurately measure time




## New Invention: Barometer

- Invented by 17th-century Italian physicist Evangelista Torricelli
- The barometer measures air pressure



Torricelli's barometer experiment

## New Invention: Thermometer



- Invented in the 17th century by Santorio Santorio, an Italian scientist
- Ferdinand II
- Gabriel Fahrenheit
- Anders Celsius





Illustration depicting Santorio's thermometer







## Galen

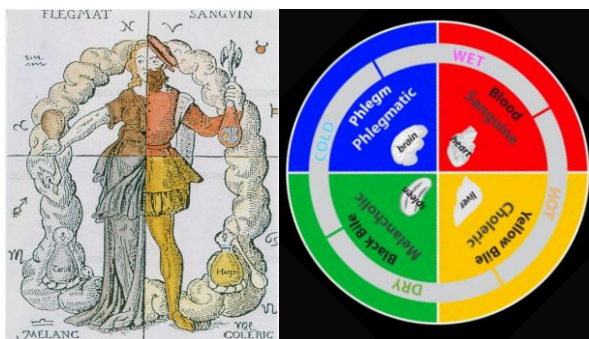


- Background
  - Roman physician 200 AD
  - Used Aristotle's theories in anatomy and medicine
  - Three books on human anatomy from observation
    - Physician to gladiators and cut up and experimented on apes (lead to mistakes)
    - Circulation wrong: blood from one chamber of the heart to another seeped through invisible pores in the dividing walls; venous and arterial systems closed, do not cross

## Medical theories (based on Aristotle; 300-600 AD)


- 4 elements in people; blood, phlegm, black bile, yellow bile
- disease=imbalance in elements; out of balance =dominant humor determines personality
- Choleric** (ego blood), **sanguine** (nervous system/astral body), **phlegmatic** (etheric or life body), and **melancholic** (physical body).



Burton's *Anatomy of Melancholy*(1) published in 1621:

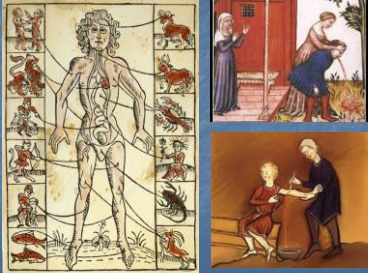
- "**Blood**, a hot, sweet, tempered, red humour,
  - prepared in the mesenteric veins, and made of the most temperate parts of the chylus (chyle) in the liver,
  - whose office it is to nourish the whole body, to give it strength and colour, being dispersed through every part of it.
  - And from it spirits are first begotten in the heart, which afterwards in the arteries are communicated to the other parts.
- "**Pituita**, or phlegm is a cold and moist humour,
  - begotten of the colder parts of the chylus
  - (or white juice coming out of the meat digested in the stomach) in the liver.
  - His office is to nourish and moisten the members of the body.
- "**Choleus** is hot and dry,
  - begotten of the hotter parts of the chylus, and gathered to the gall.
  - It helps the natural heat and senses,
- "**Melancholy**, cold and dry, thick, black and sour,
  - begotten of the more feculent part of nourishment, and purged from the spleen,
  - is a bridle to the other two humours, blood and choler, preserving them in the blood, and nourishing the bones.
- "An exact balance of the four primary humours makes the justly constituted man, and allows for the undisturbed production of the concoctions or processes of digestion and assimilation."



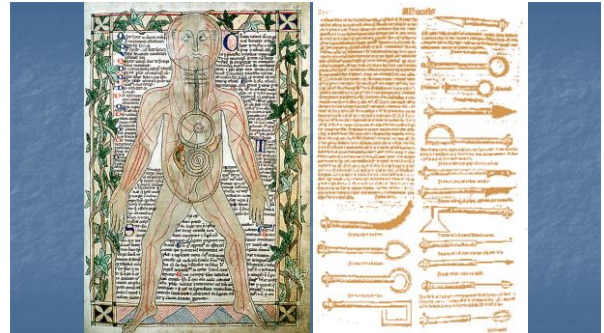


## Advances in Medicine and Chemistry

- Examination of urine became the chief method of diagnosing a patient
- Purging and bleeding harmful to patient, but often treatment with herbs helped



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## The Scientific Revolution Spreads

- Medicine and the Human Body
  - Andreas Vesalius improves knowledge of anatomy
- Received doctorate in medicine at the University of Padua
- Taught as professor of surgery



Andreas Vesalius

## Andreas Vesalius



Andreas Vesalius  
1514-1564

■ Andreas Vesalius was from a family of doctors. His great-grandfather taught medicine at the University of Leuven in Belgium.

■ Vesalius' father encouraged him to pursue a career in medicine. In 1533 he moved to France to enroll in the University of Paris.

■ In 1543, at age 28, Vesalius published the most important book to date on human Anatomy, *On the Fabric of the Human Body*.

■ Vesalius was the first to show that the heart had four chambers, the liver had two lobes, and that blood vessels originated in the heart.

## Vesalius



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- Emphasized practical research
- Wrote "On the fabric of the Human Body"
  - Personally dissected bodies to explain lecture
  - Presented examination of organs and general structure of human body
  - Made easier by artistic advances of Renaissance and advances in printing
  - Illustrations superior to anything to date

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The physician Vesalius dissected corpses to study basic human anatomy. He is now known as the "Father of Modern Anatomy."

- Able to correct much of Galen's errors
- However, he clung to several of Galen's assertions including two types of blood



Drawings from Vesalius' book *On the Fabric of the Human Body*


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**Andreas Vesalius**

Vesalius died in such poverty that his body would have been given to the animals if a kind man had not paid for his funeral. He was barely fifty years old.

Vesalius's book contained many detailed drawings of human dissections.




**William Harvey**



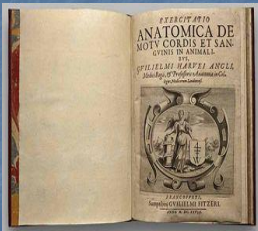
- Demonstrated many things about blood circulation
  - Emanated from the heart and not liver
  - Same blood flows through veins and arteries
  - Blood makes a complete circulation
- His theory of circulation of blood laid foundation for modern physiology

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**William Harvey**





- Wrote, "*On the Motion of the Heart and Blood*"
  - Ideas didn't achieve recognition until 1660s
  - Not until capillaries were discovered
    - Explains how blood passes from arteries to veins




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**William Harvey**

**The Scientific Revolution Spreads**



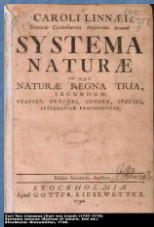
- Medicine and the Human Body (continued)
- Edward Jenner produces world's first vaccination—for smallpox



*The Cow Pock* — or — *The Wonderful Effects of the New Invention* — now, as performed by J. BARNARD, Surgeon.

1802 caricature of Jenner vaccinating patients who feared it would make them sprout cow like appendages.

## Carolus Linnaeus (1707–1778)



- Swedish botanist
- Classification and naming of flora and fauna



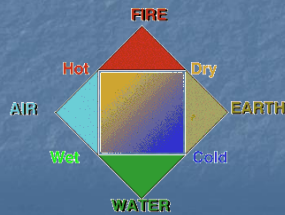
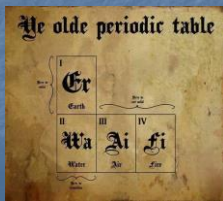
## Jean-Baptiste Lamarck (1744–1829)

- French biologist
- Early theory of evolution
- Philosophie Zoologique*
- Lamarck's "laws"



### Chemistry

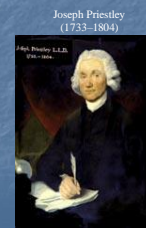
- 4 elements: earth/water/fire/air
- 5<sup>th</sup> essence perfect, indestructible, never changing
- Not until 17th and 18th centuries was there a science of chemistry



### Chemistry



Robert Boyle (1627–1691)



Joseph Priestley (1733–1804)



Antoine Lavoisier (1743–1794)

### Chemistry

- Antoine Lavoisier invented system of naming chemical elements
- Regarded by many as founder of modern chemistry



**Robert Boyle (1627–1691)** contributed to the scientific method by publishing his results in such detail that his experiments could be replicated by others. Robert Boyle argues that matter is made of many different particles

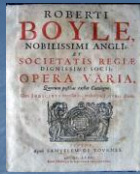
He is best known for the formulation of Boyle's Law.  
Boyle was a member of the Invisible College and of the Royal Society, as was Johannes Kepler.

**Boyle's Law:** At constant temperature and quantity, the pressure of a gas is inversely related to the volume.



## Chemistry

- Robert Boyle one of first scientists to conduct controlled experiments
  - Pioneering work on gases led to Boyle's Law
  - Explained matter was formed from atoms, later to be known as chemical elements



Boyle's vacuum chamber



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## Chemistry

- Joseph Priestley 24 March [O.S. 13 March] 1733 – 6 February 1804) was an 18th-century English chemist, natural philosopher, English Separatist theologian, innovative grammarian, multi-subject educator, and liberal political theorist who published over 150 works.
- He has historically been credited with the discovery of oxygen, having isolated it in its gaseous state, although Carl Wilhelm Scheele and Antoine Lavoisier also have strong claims to the discovery, Scheele having discovered it in 1772, two years before Priestley.



## KEY POINTS OF HIS LIFE

- Credited with the discovery of Oxygen
- Invented soda water
- His works on Electricity
- Father of Carbonation
  - Discovered a total of 9 distinct gases
  - Improving the English Grammar
- Published over 150 works!!!



## Advances in Biology and Chemistry

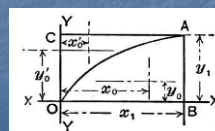
- Vesalius (Flemish)
  - 1543 *On the Fabric of the Human Body*
  - challenged Galen. ie blood flowing from one chamber to another in heart
- Harvey (British: 1578-1657)
  - demonstrated that the heart was a pump
  - Showed that blood circulated through the body
- Leeuwenhoek (Dutch--
  - Used the new microscope to see blood corpuscles, sperm, bacteria
  - Published drawings; no one took bacteria seriously as cause of disease, though

## More (advancements in chemistry)

- Boyle (1627)
  - Law on pressure of gasses
  - God's choices in creating the universe were unrestrained= unexplainable choices
  - Can experiment and experience to discover those choices, apply
  - Later, experiences on atmosphere lead him to belief in mechanistic universe (explainable by laws)
- Lavoisier(1743-1794)
  - Father of modern chemistry
  - Law of conservation of matter—cannot be created or destroyed

## Mathematics

- Math symbols for addition, subtraction, multiplication and division
- Analytical geometry: Descartes
- Calculus: Newton



$+$        $\times$   
 $-$        $\div$



## New Invention: Mechanical Calculator



Wilhelm Schickard

- Invented by Wilhelm Schickard, a 17th-century German inventor
- Gottfried von Leibniz's "Step Reckoner"



A 1624 sketch Schickard made of his calculator

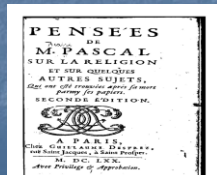
## Advances in Math

- Descartes
  - Cartesian graphing and coordinates
  - Analytical geometry
- Napier (Scot)
  - 1614 invented logarithms
- Newton/Leibniz invented calculus
- Huyghens (Dutch)
  - Calculated the force necessary to keep a planet in orbit



Blaise Pascal

- Scientist who studied probability and mathematics.
- He had concerns about science's influence on faith.
- Wrote *Pensees*, reflections on faith and science.



## The Limits of Reason...

*Can God's existence be established through empirical methods?*

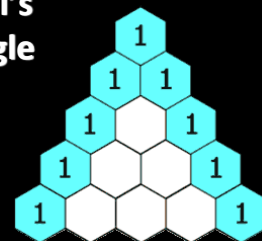


## Pascal's Wager



"God is, or He is not."

## Pascal's Triangle



## Women in the Origins of Modern Science

### Overview

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### Overview

- Women historically hampered by assigned roles
  - Daughter
  - Wife
  - Mother
- Enthusiasm for secular learning caused by humanism encouraged learned men to encourage women to study various subjects
- Persisted for privileged women into 17<sup>th</sup> century

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## Margaret Cavendish, Duchess of Newcastle-upon-Tyne (1623-1673)

- Prominent female scientist of 17<sup>th</sup> century
- Noblewoman of prominent birth
- Participated in scientific debates
- Excluded from membership in the Royal Society



Margaret Cavendish

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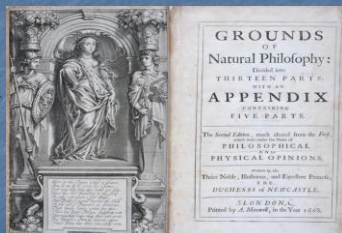
- Cavendish is famous today for her plays, letters, orations, poetry and fiction, and was a very popular writer in her time. She was prolific, publishing more than a dozen original works during her life, under her own name. Thanks to her high social status, and her husband's active and supportive interest in philosophy, she was able to personally know the best minds of her time, including René Descartes, Thomas Hobbes, Henry More, Walter Charleton, and Joseph Glanvill. She was also the first woman to be formally invited to visit the Royal Society and to observe the famous air pump experiments of Robert Boyle. At a time when many women writers were concerned predominantly with issues of religion, or the education of women, Cavendish trail-blazed her way by developing a unique position in natural philosophy which critiqued the dominant materialist, mechanist and dualist theories of substance and causation. Extravagant and eccentric, "mad Madge" stands alone as one of the few early modern women



Margaret and William Cavendish, by Gonzales Coques, 1662.

## Margaret Cavendish

- Wrote many books on scientific matters
  - *Observations upon Experimental Philosophy*
  - *Grounds of Natural Philosophy*



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- During the 1660s, Cavendish was also interested in the world of experimental philosophers such as Robert Boyle, the curator of experiments at the Royal Society, Robert Hooke, and Henry Power. On May 30th, 1667, she gained even more notoriety for being the first woman to attend a meeting of the Society. Cavendish not only attended, but she was also formally invited, partly due to the intervention of her friend Walter Charleton, who lobbied on her behalf. At the Society, she observed Robert Boyle's experiments with the air pump, and his experiments with mixing colours, with the assistance of Robert Hooke. She was delighted. The visit caused such a sensation that Samuel Pepys thought it worthy of an entry in his Diary, having spent some time pushing through the crowds to get a glimpse of her sumptuous carriage.

## Maria Merian

- Born into Swiss family
- Important entomologist
- Training in father's workshop
- Illustrations of plants and insects superb
- First illustrations at age 14



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## Maria Merian

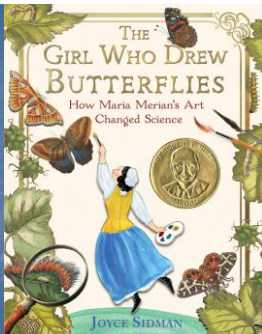
- Wrote "Metamorphosis of the Insects of Surinam"
- Sixty illustrations
- Reproductive and development cycles of Surinam's insect life



■ Maria Merian illustration, 1730

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## Maria Winkelmann

Leipzig, 1670 - Berlin, 1720

La primera mujer astrónoma  
que en 1702 descubrió  
el cometa C/1702 H1

Collage: Silvia Piquero

## Maria Winkelmann

- Born in Germany (1670-1720)
- Craft organization of astronomy gave women a chance at science
- Encouraged and educated by father and uncle
- Most famous of female astronomers
- Married famous astronomer Gottfried Kirch



Discovered comet

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## Maria Winkelmann



- Denied post at Academy of Berlin
- Women denied acceptance into Royal Academy of Sciences and French Academy of Sciences
- Science considered man's domain until 20<sup>th</sup> century

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- In Germany, traditional women participated in craft production, paving the way for women in observational science
- Between 1650 and 1710, one of every seven German astronomers was a woman

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### Debates on the Nature of Women

- Ongoing debates—"querelles des femmes"—
- Male opinions carryover from middle ages
  - Women were inherently base, prone to vice, easily swayed, and "sexually insatiable"
  - Hence, men needed to control them
- Learned women seen as overcoming liabilities

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### Debates on the Nature of Women

- Unfortunately, science was used to support old stereotypes about women
  - Larger pelvic area justified women for child bearing
  - Small head for justified lesser intellect
  - Males took over traditional female roles like midwife duties and others, except among poor

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### Debates on the Nature of Women

- History would expect a era of scientific discoveries would foster more openness to female acceptance, but...
  - Scientific Revolution affirmed beliefs about women. Male scientists used science to justify that women belonged in the home
  - Differences in physiology of women highlighted

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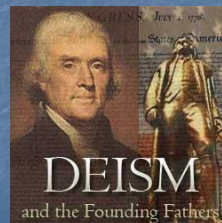
### Debates on the Nature of Women

- Male used new scientific devices and knowledge to take over traditional services performed by women such as midwifery
- Midwives continued to serve the poor
- Scientific Revolution endeavored to justify the belief in the inferiority of women

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### IV. Consequences of the Scientific Revolution



- Laws discovered by human reason
- "De-Spiritualized" and de-mystified the Universe
- Mechanical View of the Universe
- Deistic View of God
  - --God as the cosmic capitalist

**Charles-Louis Montesquieu (1689–1755)** was a French political scientist.  
 ■ He claimed that there were three main forms of government, each based on a "social principle."  
 ■ These were monarchies, republics (governments headed by popularly elected leaders), and despotisms ruled by dictators.



**Thomas Hobbes** was a 17th-century political scientist and philosopher and proponent of materialism, the belief that all that exists is matter which can be understood empirically.  
 ■ Hobbes explains his theory of the social contract in his book, *Leviathan*.  
 ■ He concluded that the state is ultimately derived from the consent of the people.



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**Baruch Spinoza** was a 17th-century Dutch rationalist.  
 ■ Spinoza believed that everything comes from a divine origin, but that human reason is too limited to comprehend all of divine will.



**John Locke** was a 17th-century philosopher and empiricist.  
 ■ His political ideals influenced the American Revolution.  
 ■ As an empiricist, he held that the world could only be experienced through the senses.  
 ■ Locke developed the idea of the social contract, whereby governments arise to regulate the natural human tendency to defend "life, health, liberty, or possessions."



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**Jean Jacques Rousseau (1712–1778)** was a 18th-century philosopher from Geneva.  
 ■ His political philosophy influenced the French Revolution.  
 ■ His novel *Emile* is a treatise on education that discusses the rights of the citizen.



**David Hume** (1711–1776) was a Scottish empiricist and a leader in the Scottish Enlightenment.  
 ■ The 18th-century Scottish Enlightenment was a time when many intellectual and scientific advances were made by Scottish thinkers.



**Immanuel Kant (1724–1804)** established a method of inquiry called "transcendental idealism," which stated that humans understand things subjectively, as they appear to us.  
 ■ He believed that neither rationalism nor empiricism alone could explain nature.  
 ■ He wrote that reason is necessary for understanding the empirical results.



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**The American colonists** rejected the power of the English Parliament to govern the colonies without representation.  
 ■ The increases in taxation and civil repression by King George III led the American colonists to revolt against England's rule and form independent states.  
 ■ Many of the ideas about liberalism and personal freedom of the American Revolution came from John Locke's theory of the social contract.



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