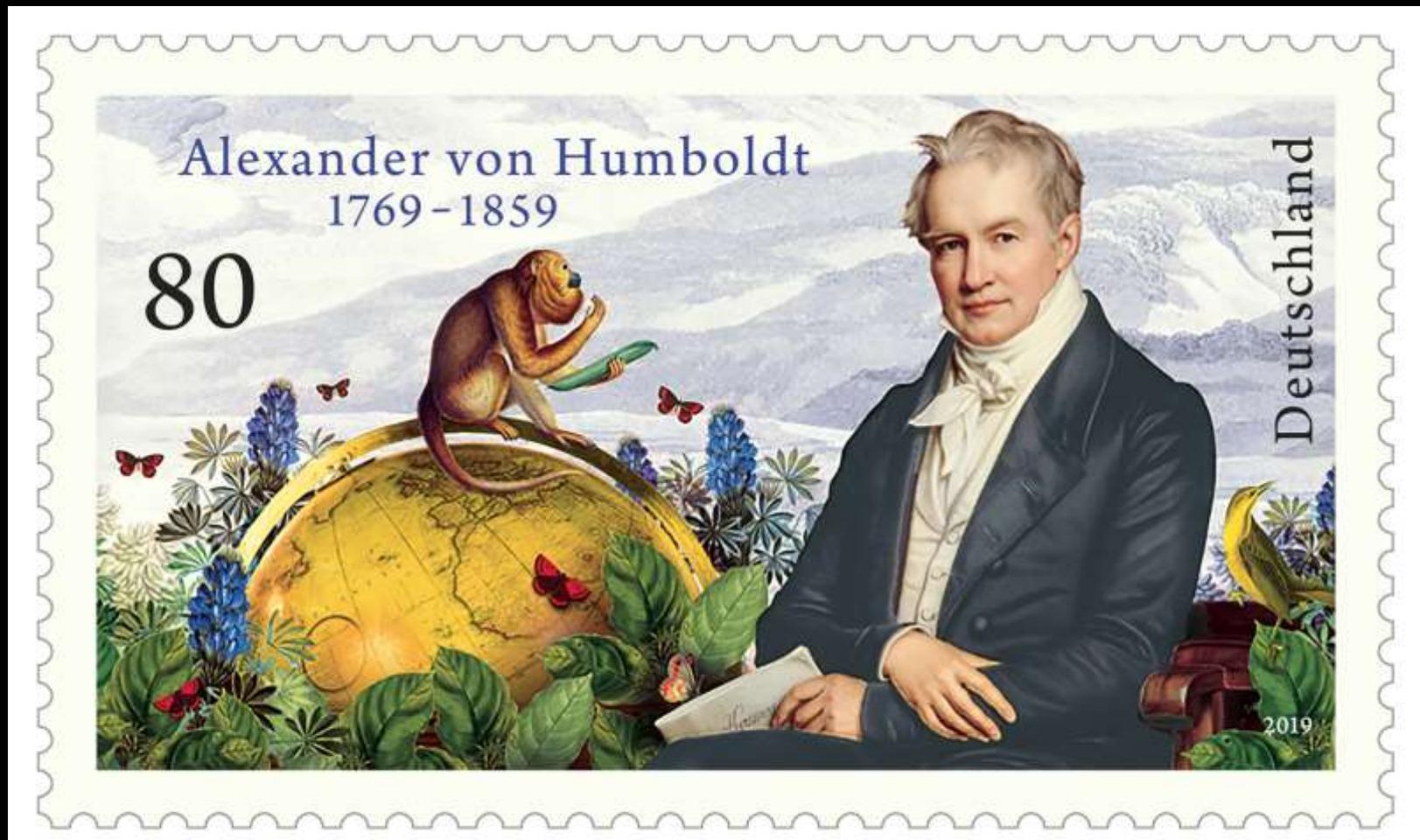




**2022 CER Lunchtime Lectures  
Humboldt, Science, and The Geography of Nature**





# Center for Environmental Research at Hornsby Bend



## Mission – A Partnership for Urban Ecology and Sustainability

- Community
- Education
- Research

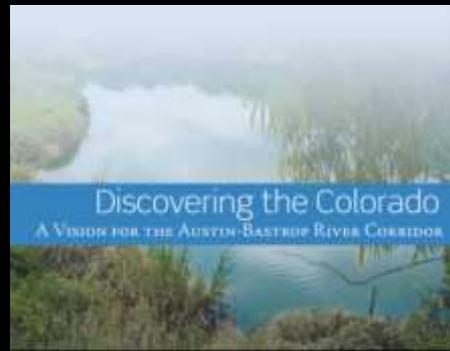


## Partners

- Austin Water
- The University of Texas
- Texas A&M University

## Programs and Research Areas

- The Hornsby Bend Bird Observatory Program
- The Austin-Bastrop River Corridor Partnership
- The Lunchtime Lecture Series
- Urban Ecology
- Avian Ecology
- Hydrogeology
- Riparian Ecology

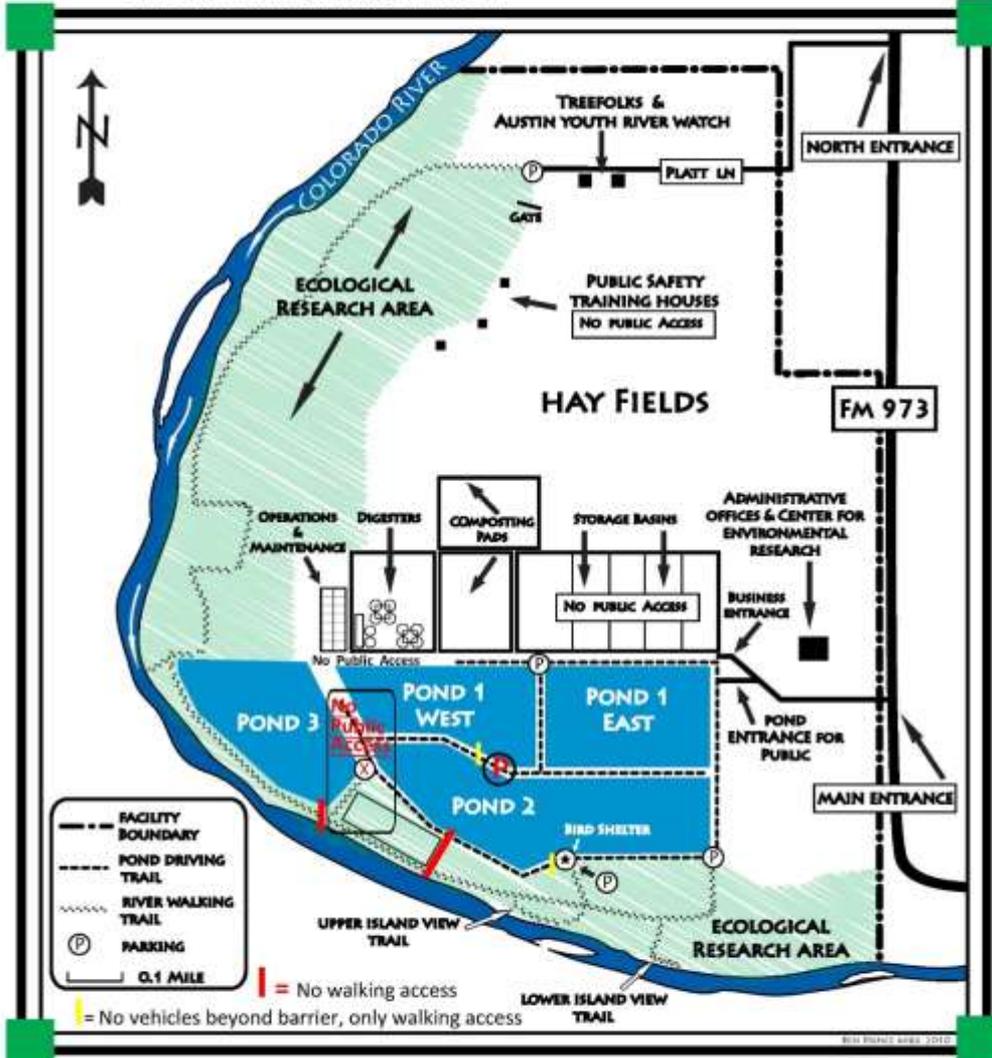


The Center for Environmental Research open for public restroom access

# HORNSBY BEND BIOSOLIDS MANAGEMENT PLANT



FACILITY OPEN TO THE PUBLIC DAWN TO DARK EVERY DAY OF THE WEEK  
2210 SOUTH FM 973, AUSTIN, TEXAS 78725



For more information contact the Austin Water-CER 512-972-1960

Dillo Dirt and Hornsby Bend Plant - [www.austintexas.gov/water](http://www.austintexas.gov/water)  
The CER Hornsby Bend Bird Observatory program - [www.hornsbybend.org](http://www.hornsbybend.org)  
The AW Center for Environmental Research [CER] - [www.austintexas.gov/cer](http://www.austintexas.gov/cer)

CER on Facebook - <https://www.facebook.com/austinwatercer>  
CER on Instagram - <https://www.instagram.com/austinwatercer/>  
Hornsby Bend on Facebook - <https://www.facebook.com/hornsbybend>

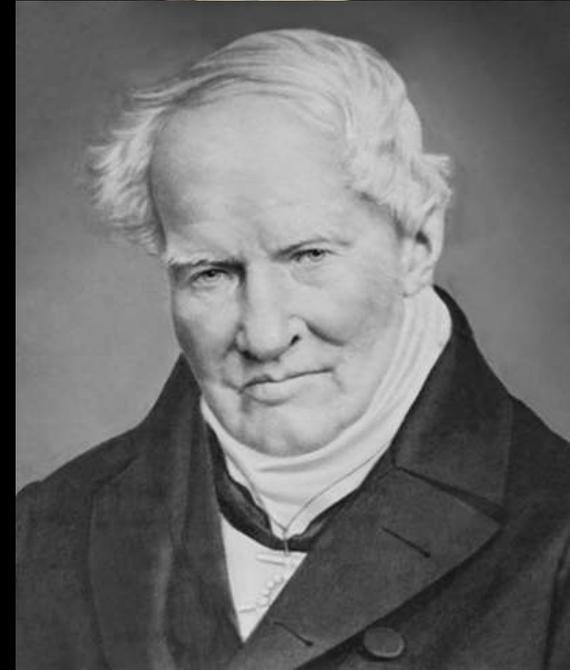


Austin Water  
Hornsby Bend Biosolids  
Management Plant



The Center for Environmental Research

Alexander von Humboldt (1769-1859)



# Alexander von Humboldt and Aimé Bonpland 1799-1804

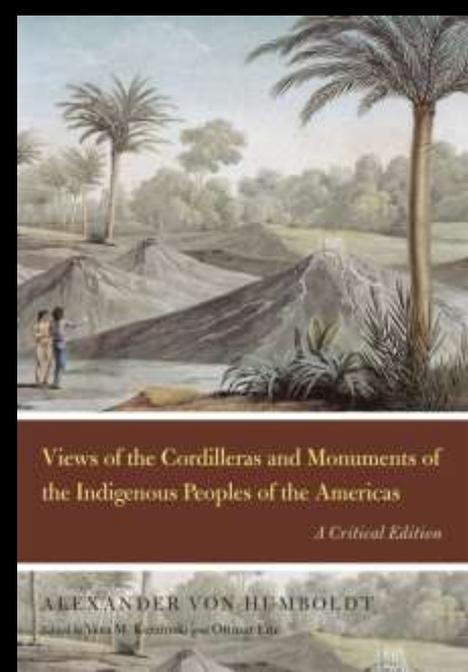
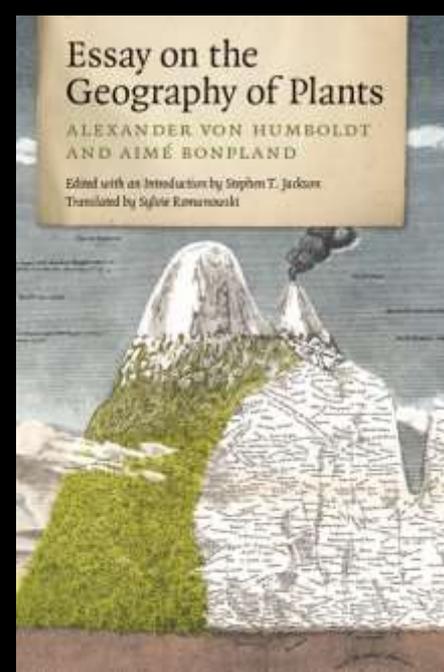
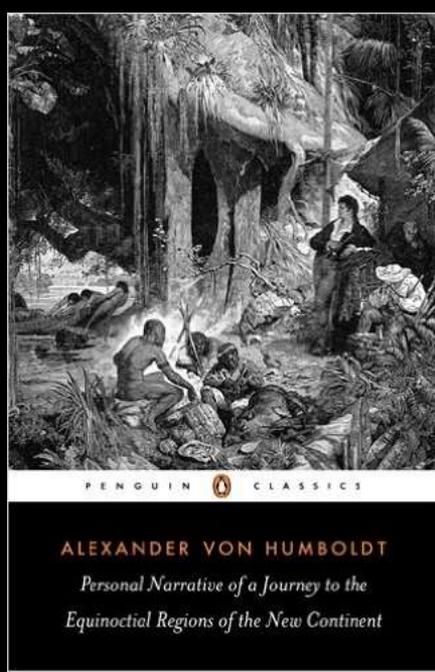
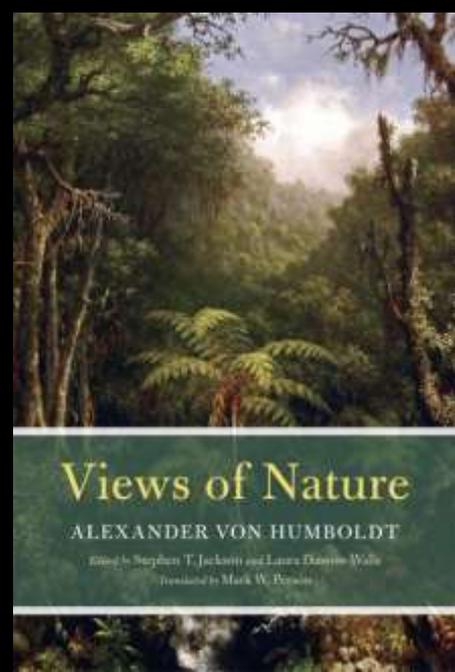


**Alexander von Humboldt's American expedition 1799-1804**

- Expedition way
- City / Stopping place
- Spanish Viceroyalties and United States

- I** With the spanish corvette "Pizarro" from La Coruña over the Canary Islands to Cumaná
- II** 75-days journey with Bonpland, on the Orinoco and the Rio Negro
- III** With the ship from Nueva Barcelona to Havana, 3-month sojourn on Cuba, over Trinidad to Cartagena
- IV** Through today's Colombia, Ecuador and Peru to Lima
- V** From Guayaquil to Acapulco, longer sojourn in Mexico-City and back to Havana over Veracruz
- VI** With the cargo ship "Concepción" to Philadelphia, Washington, with the french Frigate "La Favorite" to Bordeaux



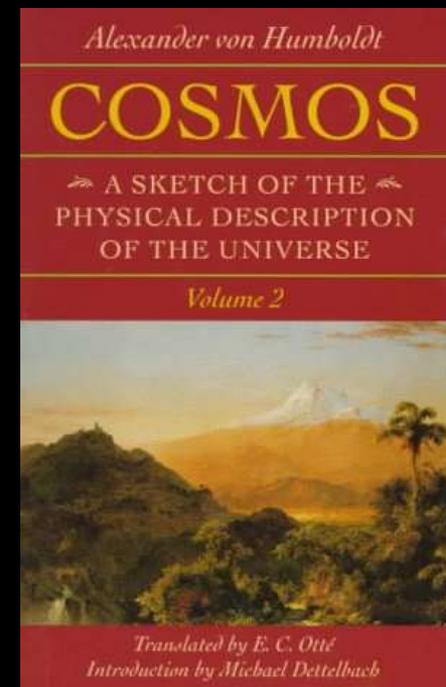
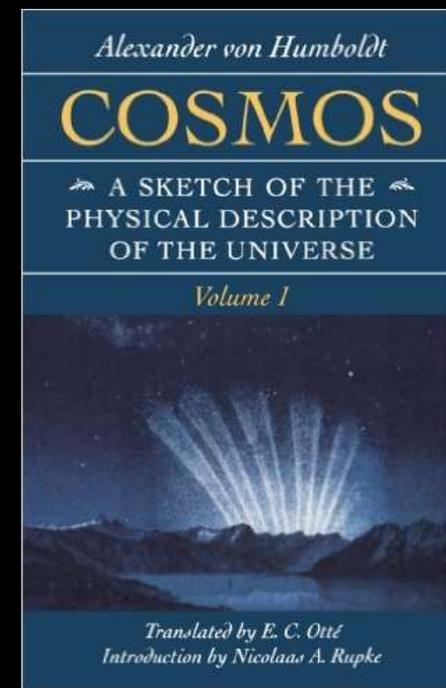
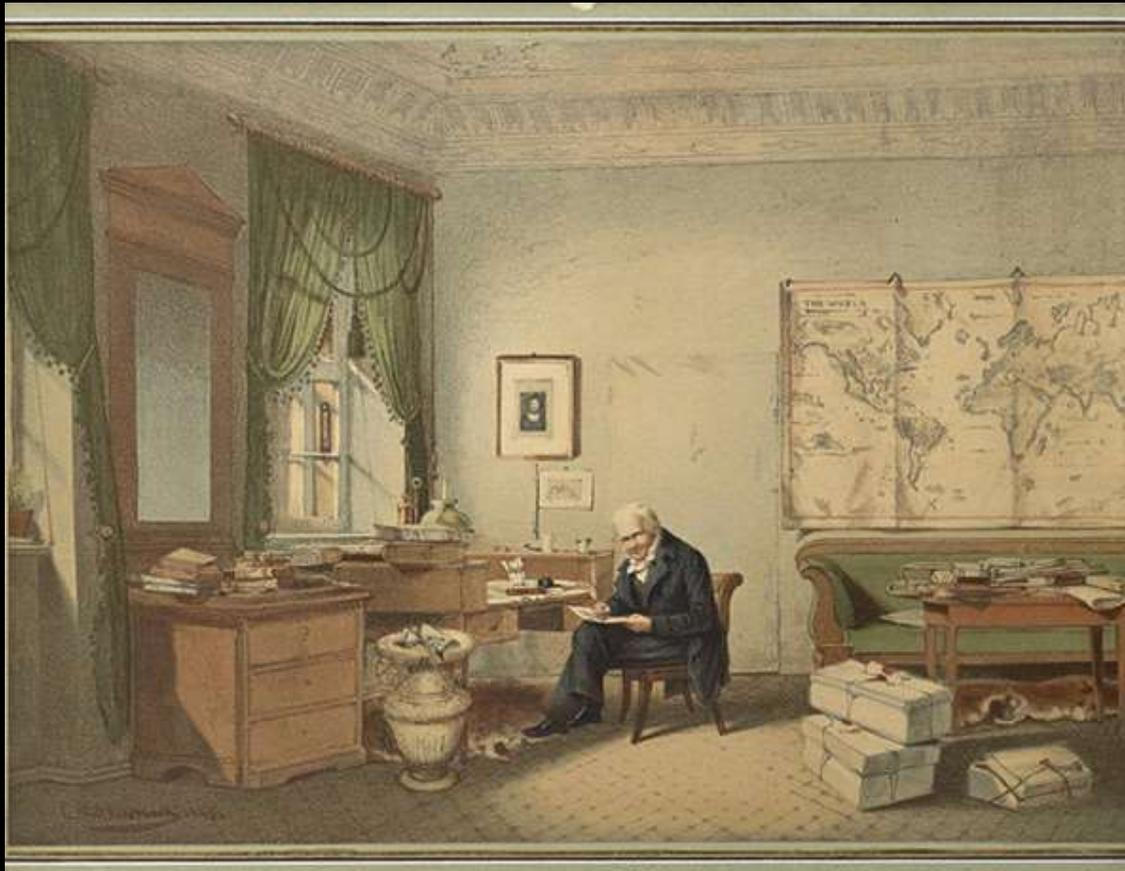


# Cosmos: A Sketch of the Physical Description of the Universe

Humboldt's five-volume opus *Cosmos* (1845-1862)

*Cosmos* was the scientific bestseller of the age - the first edition of the first volume sold out in two months

- 1845 Humboldt was 76, the second volume published when he was 78, the third when he was 81, and the fourth when he was 89
- The fifth volume, however, was only half-written when Humboldt died in 1859





## 2022 CER Lunchtime Lectures - Humboldt, Science, and The Geography of Nature

### Western Culture and the Study of Nature

January – Natural Philosophy and the Study of Nature

February – Natural History and the Taxonomy of Nature

March – Ecological Imperialism and the Geography of Nature

April – Physical Geography and the Science of Nature

### Humboldt and the Science of Nature

May – The Science of Nature: Humboldt and the Empirical Earth

June – The Romance of Nature: Science, Imagination, and the Poets of Nature

July – The Invention of Modern Nature: The Earth as a “Natural Whole”

August – The Evolution of Nature: Humboldt, Darwin, and Biogeography

September – The Economy of Nature: Ecology, Culture, and Cosmos

### Humboldt and the Geography of Nature

October – The Great Disruptors: Physical Geography as Modified by Human Action

November – The Earth Managers: New Science and Environmental Change

December – The Anthropocene: Gaia and the Geography of Nature





## Western Culture and The Study of Nature

January – Natural Philosophy and the Study of Nature

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April – Physical Geography and the Science of Nature

### A HISTORY OF NATURAL PHILOSOPHY

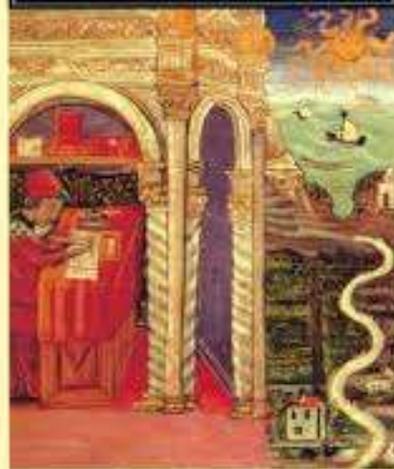
*From the Ancient World to  
the Nineteenth Century*



EDWARD GRANT

CAMBRIDGE

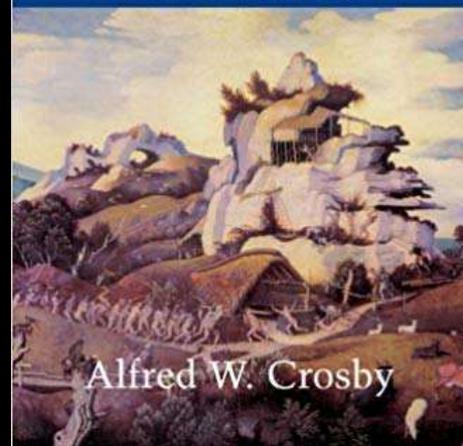
### PENGUIN CLASSICS PLINY THE ELDER NATURAL HISTORY A SELECTION



### ECOLOGICAL IMPERIALISM

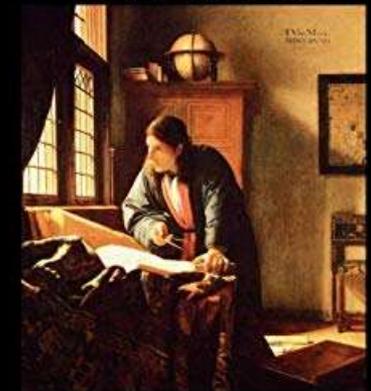
The Biological Expansion  
of Europe, 900–1900

NEW EDITION



Alfred W. Crosby

### The Geographical Tradition



DAVID N. LIVINGSTONE

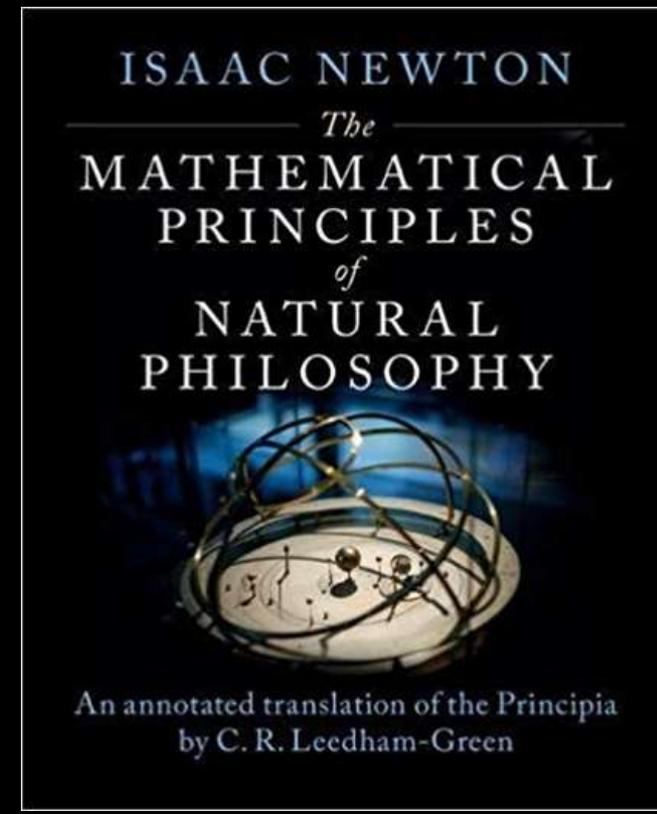
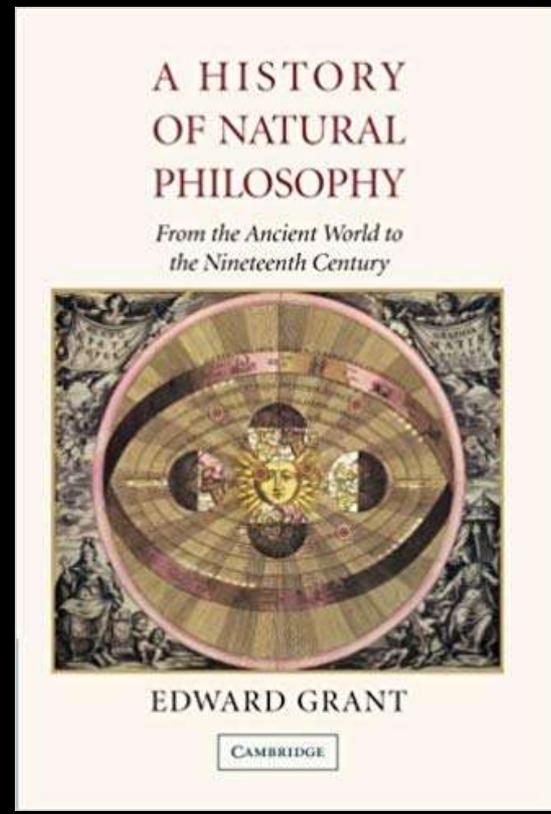
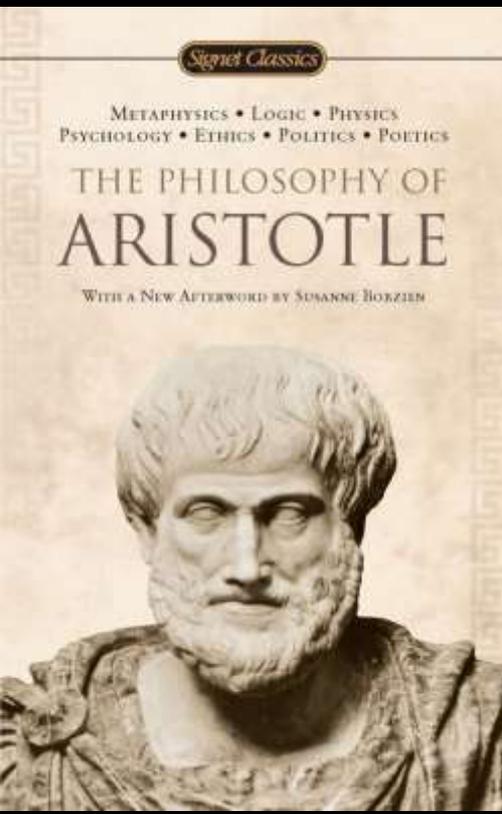
Blackwell  
Publishing



## Natural Philosophy and the Concept of Nature

Kevin M. Anderson

Austin Water Center for Environmental Research



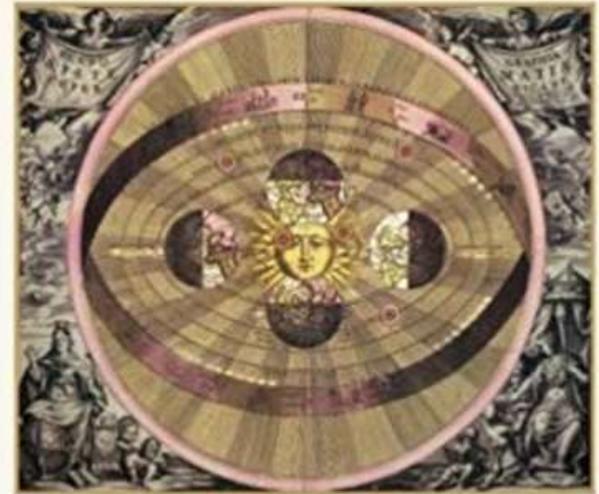
## Natural Philosophy

### “The Great Mother of the Sciences”

- From the ancient world, starting with Aristotle, to the 19th century, natural philosophy was the common term for the practice of studying nature (*physica* - the physical universe) that was dominant before the development of modern science.
- Natural philosophy was distinguished from the other precursor of modern science, natural history, in that natural philosophy involved reasoning and explanations about nature, whereas natural history was a more qualitative and descriptive study of nature.
- “Science” (from the Latin word *scientia*, meaning “knowledge”) was a broader term for different types of knowledge about ethics, politics, art, crafts, mathematics, astronomy, and physical nature.

## A HISTORY OF NATURAL PHILOSOPHY

*From the Ancient World to  
the Nineteenth Century*



EDWARD GRANT

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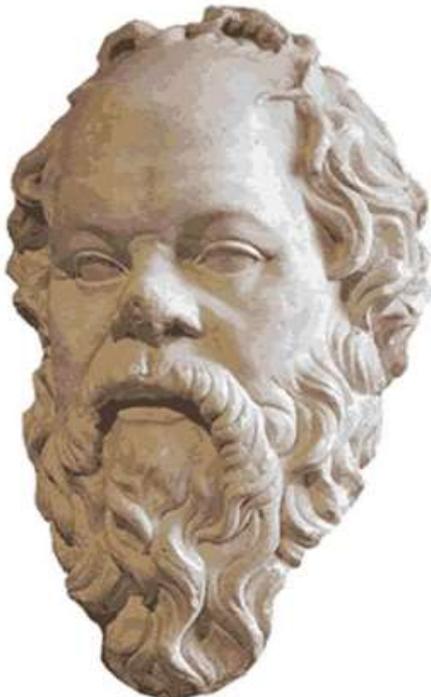
Francis Bacon – Natural Philosophy was “The Great Mother of the Sciences”

# Natural Philosophy and Western Culture

## Greek Philosophers

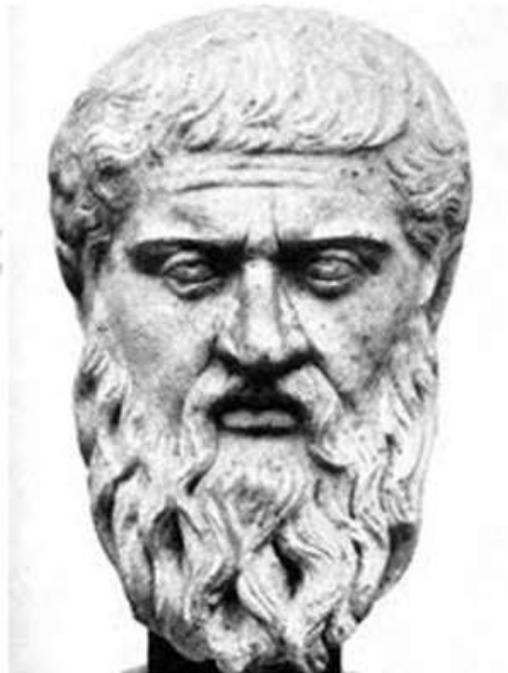
**Socrates**

470-399 B.C.



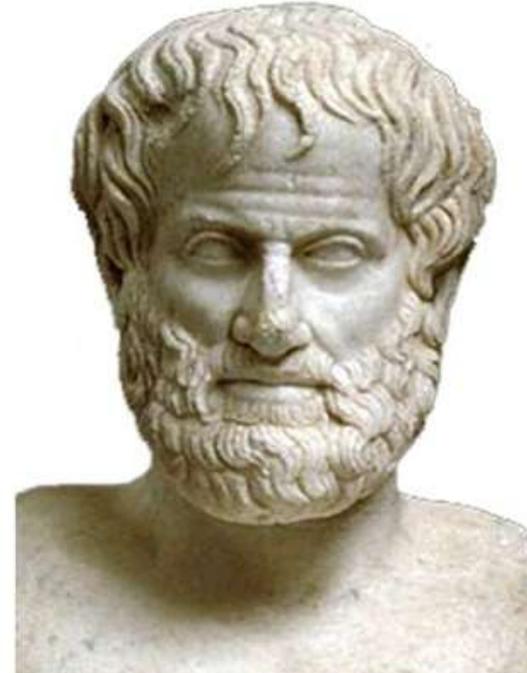
**Plato**

428-348 B.C.

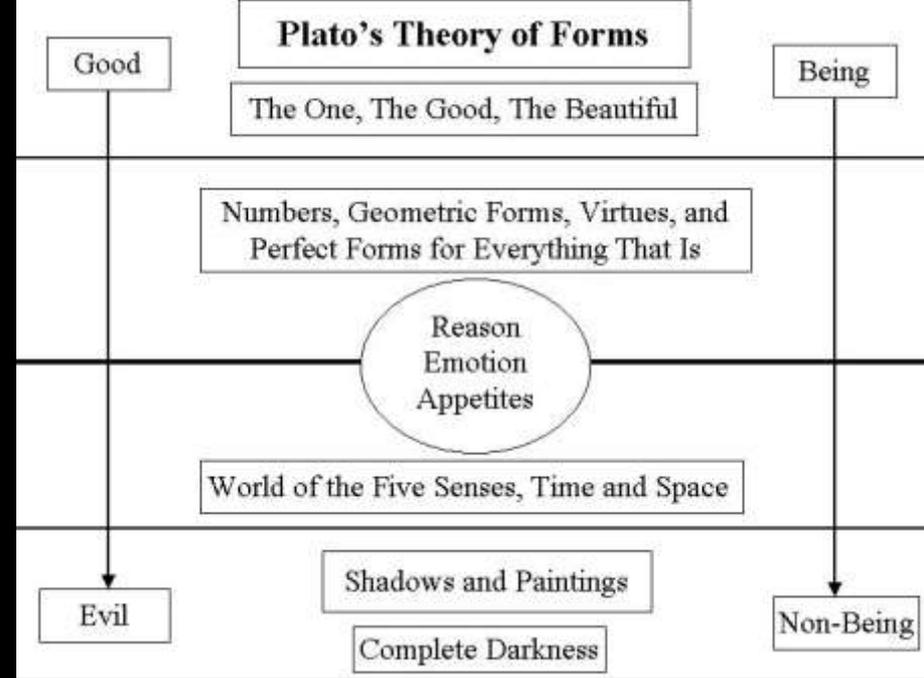
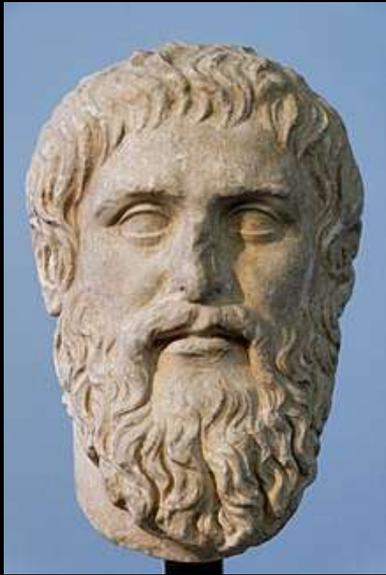


**Aristotle**

384-322 B.C.



# Plato's Philosophy and the Study of Nature

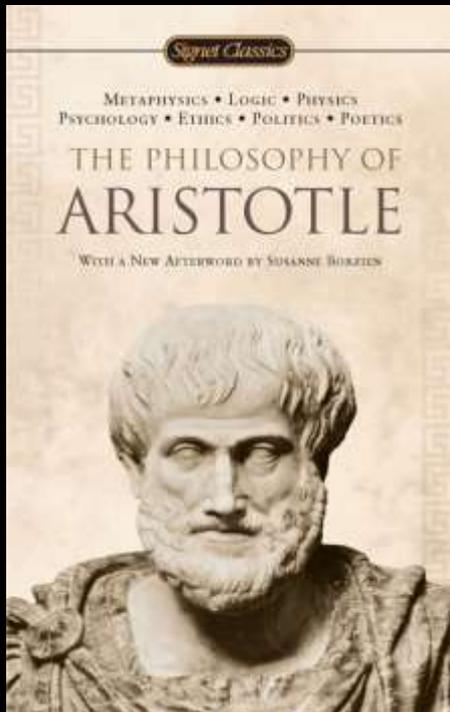


- The most fundamental distinction in Plato's philosophy is between the many observable objects that appear beautiful (good, just, unified, equal, big) and the one object that is what beauty (goodness, justice, unity) really is, from which those many beautiful (good, just, unified, equal, big) things receive their names and their corresponding characteristics.
- Plato believed that the true substances are not physical bodies, which are ephemeral, but the eternal Forms of which physical bodies are imperfect copies. These Forms not only make the world possible, they also make it intelligible, because they perform the role of universals.
- Similarly, the human body is imperfect and ephemeral, but the human soul/mind is eternal and capable of knowing truth – the Forms.
- The Allegory of the Cave - the invisible world is the most intelligible and trustworthy, but the visible world known through senses is the least trustworthy and the most unreliable.

Plato (left) and Aristotle (right), a detail of *The School of Athens* (1510), a fresco by Raphael.

Aristotle gestures to the earth, representing his belief in knowledge through empirical observation and experience, while holding a copy of his *Nicomachean Ethics* in his hand.

Plato gestures to the heavens, representing his belief in the Forms while holding the *Timaeus*.

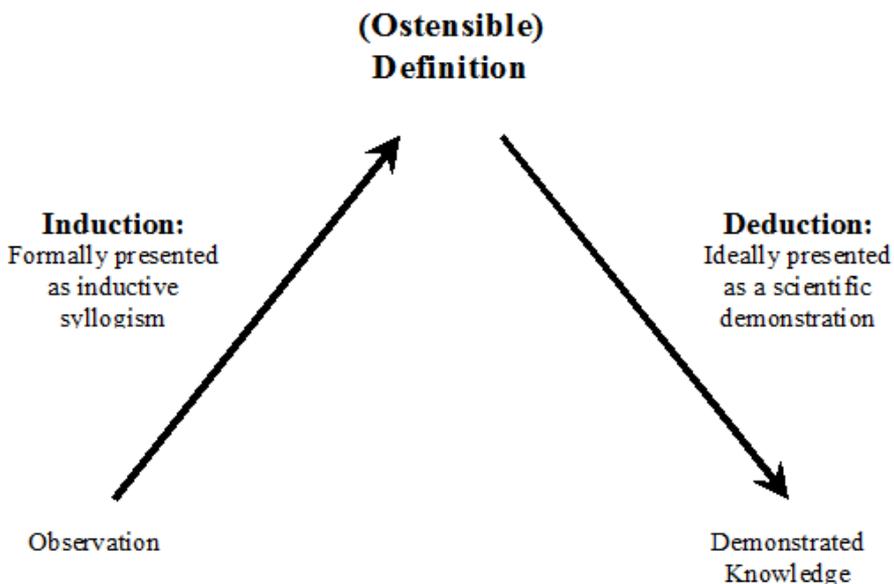
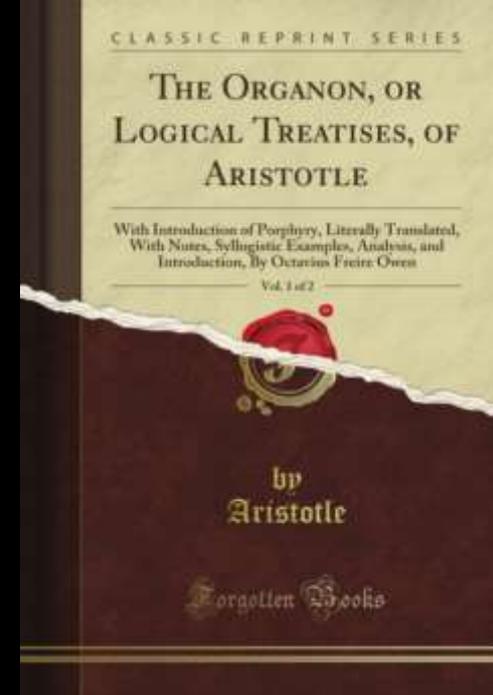


# Aristotelian Logic, Knowledge, and Nature

Aristotle's logical treatises are called the *Organon* - Greek for "tool"

Like his teacher Plato, Aristotle's philosophy aims at the universal.

Aristotle, however, found the universal in particular things, which he called the essence of things, while Plato finds that the universal exists apart from particular things, and is related to them as their independent prototype (and eternal exemplar) the Form.



- For Plato logic means the descent from a knowledge of universal Forms (or ideas) to a contemplation of particular imitations of these (deduction) producing a logic of relation to ideals.
- For Aristotle, therefore, logic implies the ascent from the study of particular phenomena to the knowledge of essences (induction) producing a logic that tells us what belongs to what (kinds).
- Spiders have eight legs.

# Aristotle – Three Types of Knowledge

## The Theoretical Sciences

- Universal Knowledge

## The Productive Sciences

- Making of useful objects

## The Practical Sciences

- Human Conduct



## Aristotle's Three Types of Knowledge

### Episteme (Scientific Knowledge)

Universal, context-free and objective knowledge  
(explicit knowledge)

### Techne (Skills and Crafts Knowledge)

Practical and context-specific technical know-how  
(tacit knowledge)

### Phronesis (Practical Wisdom)

Experiential knowledge to make context-specific  
decisions based on one's own value/ethics (high  
quality tacit knowledge)

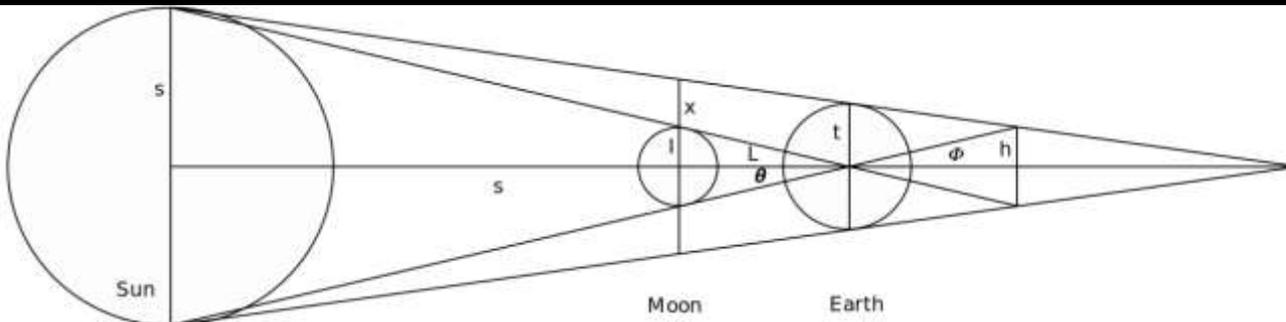
© Nensaku Toyama-Kondo

## The Theoretical Sciences

- Physics/Natural Philosophy
- Metaphysics – things that are unchangeable, distinct from body/matter, eternal substance (God)
- Mathematics – things that are unchangeable but are abstractions from physical entities with no separate existence

# The Problem of the “Exact Sciences” and Medicine

- Mathematics – things that are unchangeable but are abstractions from physical entities with no separate existence
- The “Exact Sciences” - Astronomy, Optics, Mechanics (mathematical sciences)
- In Astronomy, where does the balance lie between the mathematical and the physical?...Must the astronomer concern himself with the real structure of things, as Aristotle’s astronomical scheme suggests?” Lindberg 2007
- Medicine – Productive Science? Theoretical Science?



“As entertaining and educational as that organized by the best tour operator.”  
—CHARLES BURNETT, *New York Times Book Review*



## The Beginnings of Western Science

*The European Scientific Tradition in  
Philosophical, Religious, and Institutional  
Context, Prehistory to A.D. 1450*

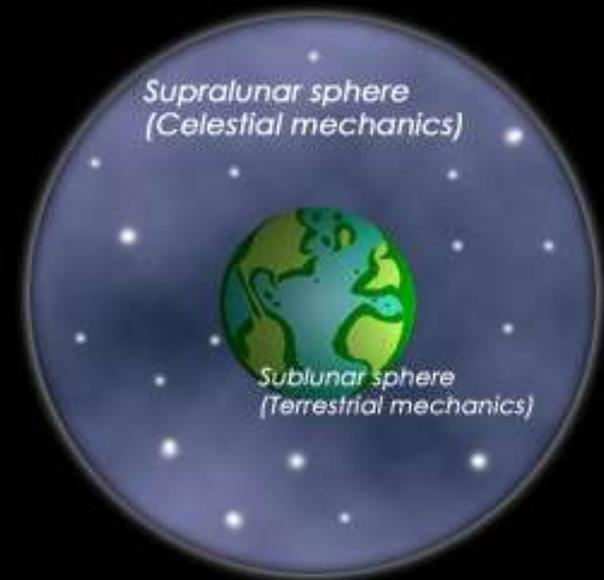
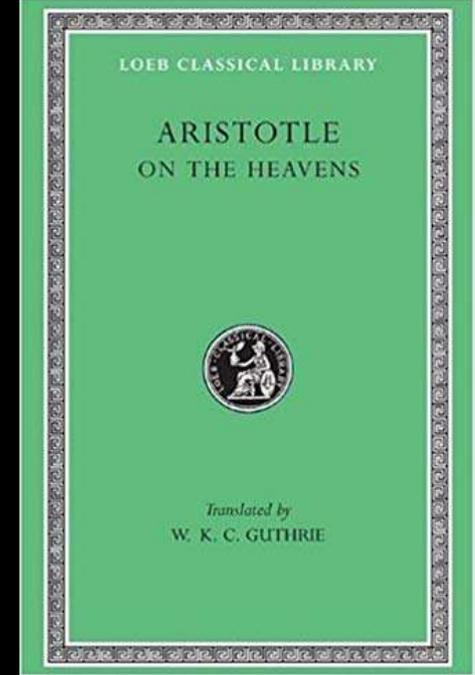
SECOND EDITION

DAVID C. LINDBERG

# Aristotle's Cosmos

- In his books *On the Heavens*, and *Physics*, Aristotle put forward his notion of an ordered universe or Kosmos
- The Cosmos is divided into two distinct parts, the sublunary region and the celestial region
- Sublunary – from Earth to Moon - the abode of change and corruption
- Celestial – the region of perfection, where there is no change
- The Cosmos is governed by the concept of place, as opposed to space
- Everything had its natural place, a privileged location for bodies with a particular makeup
- All is a continuum - there were no empty places (vacuum) anywhere
- Finally, it was finite: beyond the Cosmos, there was nothing, not even space.
- The Cosmos encompassed all existence and had no temporal beginning or end – eternal

Some of these features will later cause problems for Western religion and science...

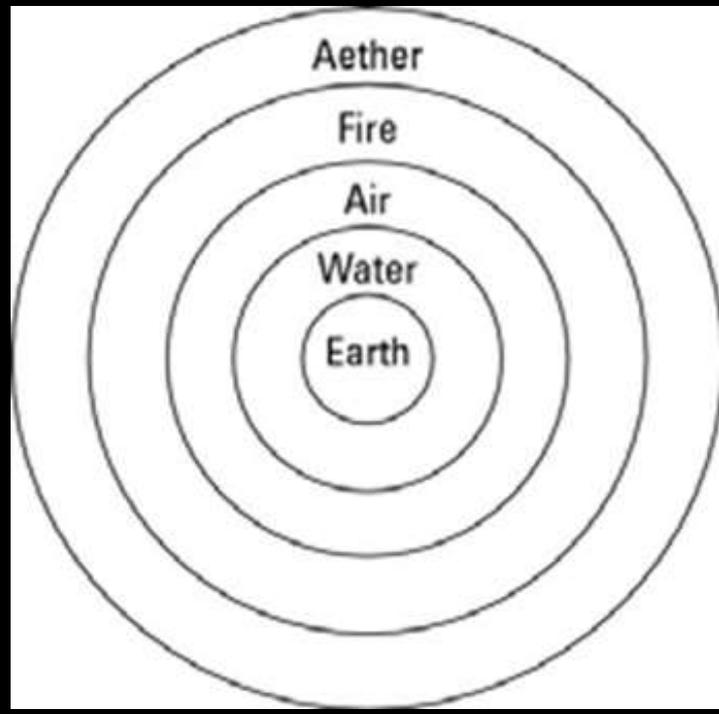
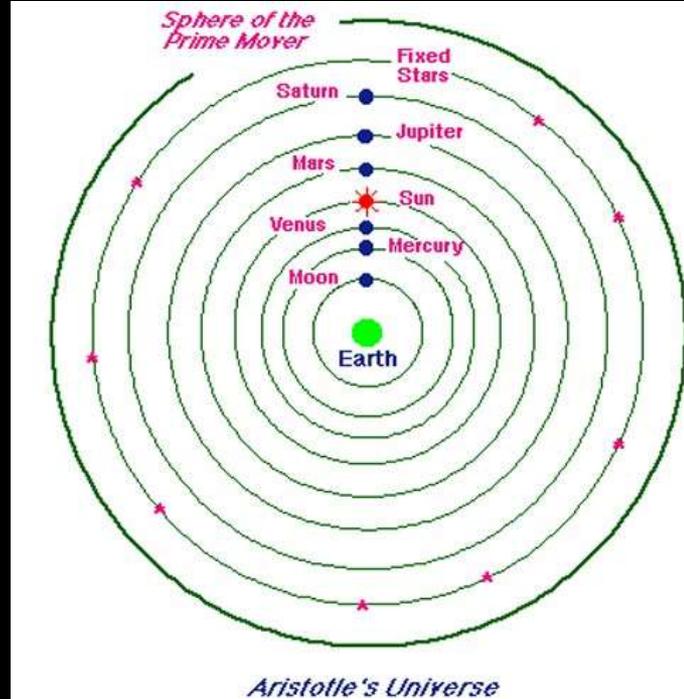


*Aristotelian Cosmology (simplified)*

# Astronomy, Theology, and Aristotle's Cosmos

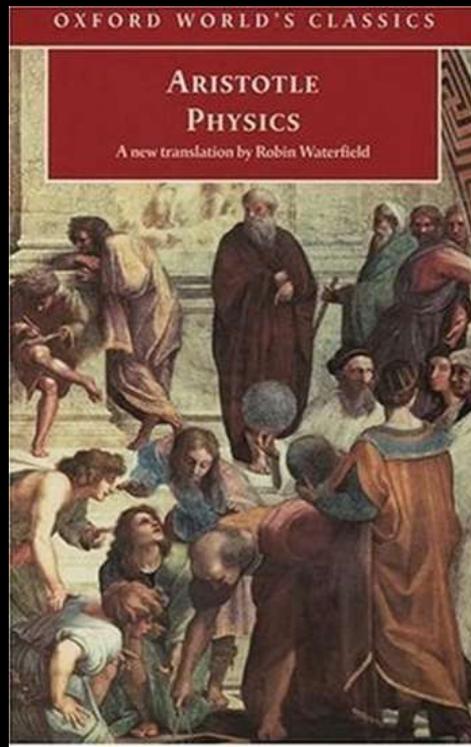
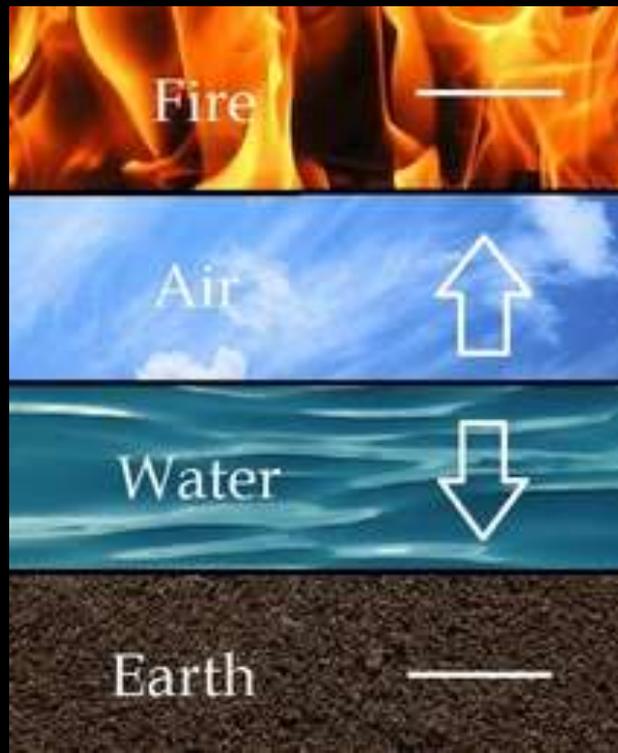
- Heavenly bodies were part of spherical shells of aether (the fifth element or Quintessence).
- These spherical shells fit tightly around each other, without any spaces between them with the Earth in the center (Geocentric).
- The natural motions of heavenly bodies and their spheres are perfectly circular and neither speeding up nor slowing down.
- Outside the sphere of the fixed stars, there is the Prime Mover (himself unmoved), who imparted motion from the outside inward.
- All motions in the cosmos came ultimately from this Prime Mover, who is eternally unchanging and does not intervene in the world. (this will later be a problem for Christian theology)

Problem - tension between belief in celestial perfection and reality of celestial imperfection for astronomy



# Aristotle's *Physics*/Natural Philosophy

- The Sublunary Region
- Things with separate existence (individual particulars)
- Things that are changeable – where things come into being, grow, mature, decay, and die
- How to explain Order and Change?
- Four Elements – Earth, Water, Air, Fire
  - All physical things made of two or more elements
  - Earth and Water = heavy, move downward
  - Air and Fire = light, move upward
  - Motion, Change, Transformation explained by elements



# Natural Philosophy

## Motion and Change – 4 Causes

- Material cause - An object's motion will behave in different ways depending on the [substance/essence] from which it is made. (Compare clay, steel, etc.)
- Formal cause - An object's motion will behave in different ways depending on its material arrangement. (Compare a clay sphere, clay block, etc.)
- Efficient cause - That which caused the object to come into being; an "agent of change" or an "agent of movement".
- Final cause - The reason that caused the object to be brought into existence.

Teleology – all things have a purpose

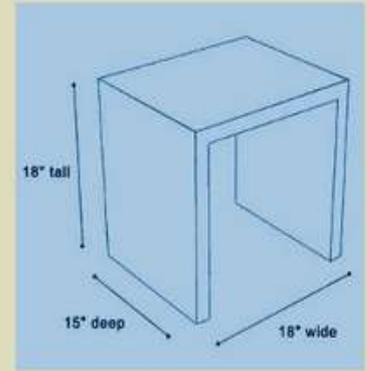
# Aristotle's Four Causes



## The Material Cause

The material out of which the thing exists

e.g. - A table's material cause is **wood**.



## The Formal Cause

The form in which the thing is arranged

e.g. - A table's formal cause is the idea of **an elevated flat surface**.



## The Efficient Cause

The 'mover' that causes the thing to be or happen

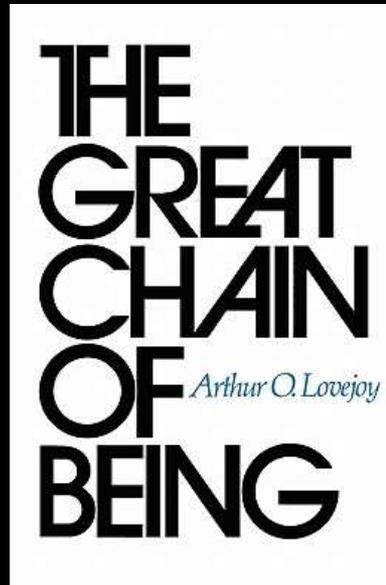
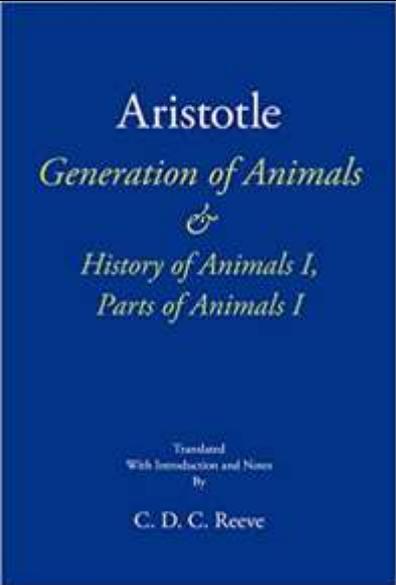
e.g. - A table's efficient cause is **the carpenter** that made it.



## The Final Cause

The purpose for which the thing exists

e.g. - A table's final cause is **to be used to place food or other things on**.



# Natural Philosophy – “Scala Naturae” The Classification of Living Things

Aristotle's classification of living things is a first attempt at taxonomy. What the modern zoologist would call vertebrates and invertebrates, Aristotle called 'animals with blood' and 'animals without blood'

Aristotle's *History of Animals* classified organisms in relation to a hierarchical “Great Chain of Being” (*scala naturae*), placing them according to complexity of structure and function so that higher organisms showed greater vitality and ability to move

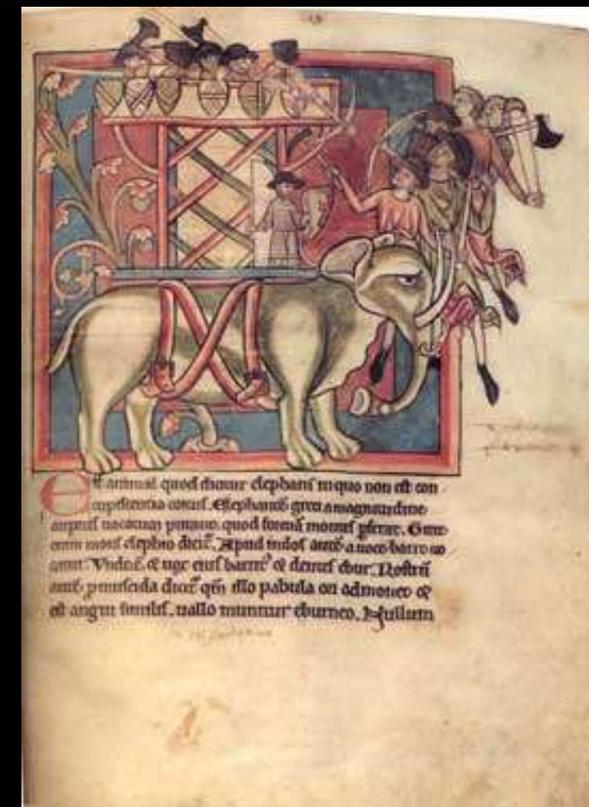
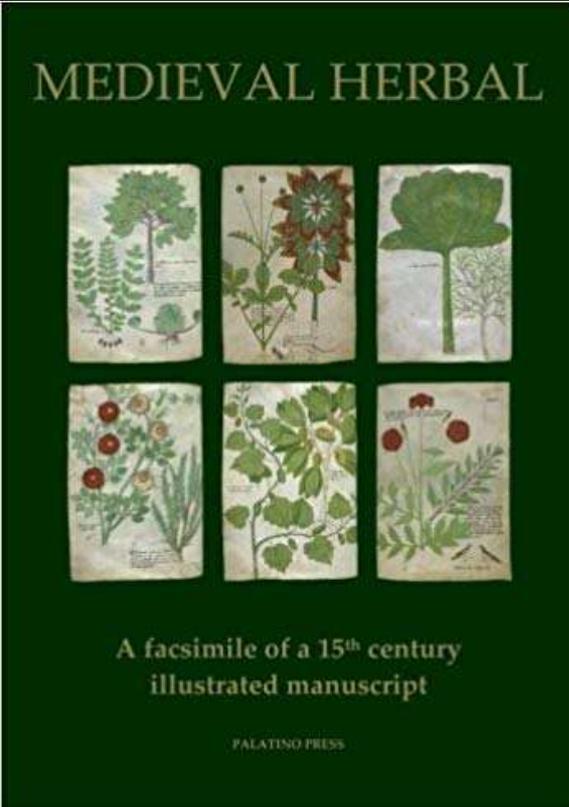
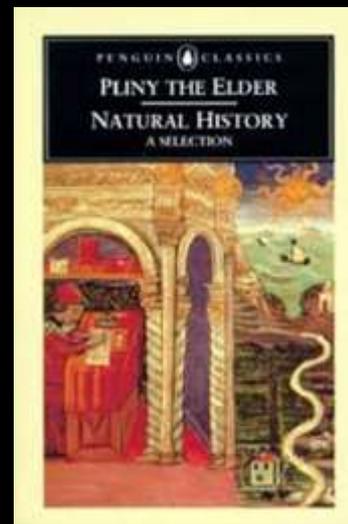
He ranked animals over plants based on their ability to move and sense, and graded the animals by their reproductive mode, live birth being "higher" than laying cold eggs, and possession of blood, warm-blooded mammals and birds again being "higher" than "bloodless" invertebrates

The Great Chain of Being is a graded scale of perfection rising from plants on up to humans at the top since humans are the “rational animal”

	ability to grow and reproduce	ability to move	ability to think rationally
Humans	X	X	X
Animals	X	X	
Plants	X		
Minerals			

# Roman and Medieval Natural History vs. Natural Philosophy

- Natural Philosophy = Aristotle
- Natural History (Descriptive and Observational)
- Bestiaries
- Herbals - Medicine

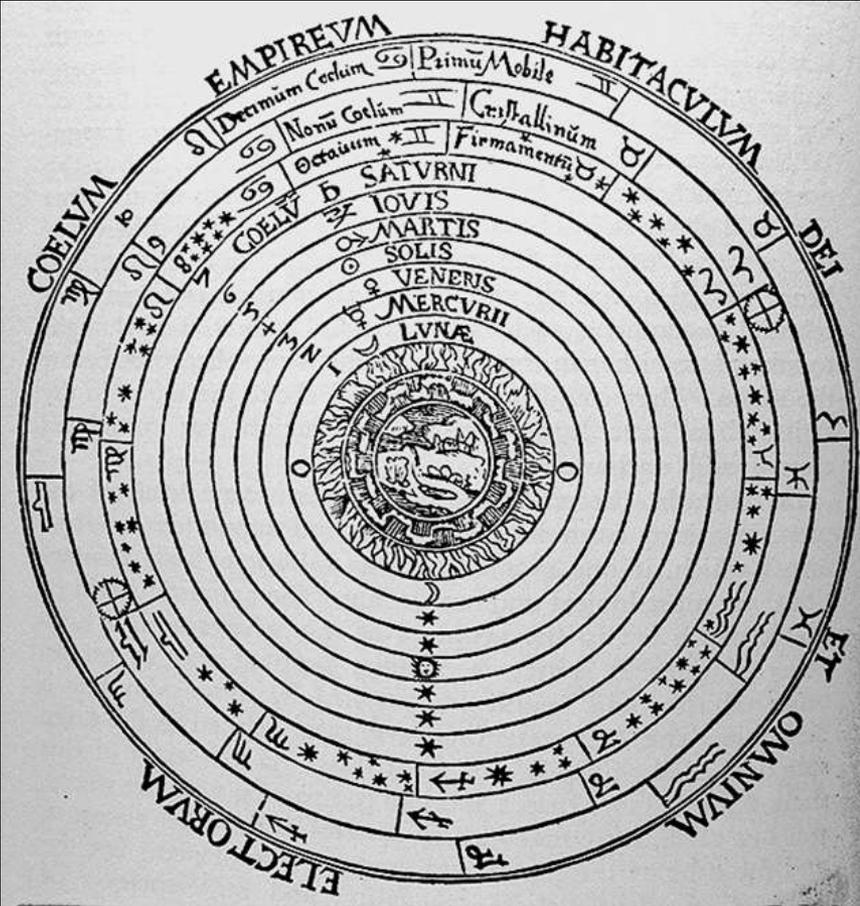
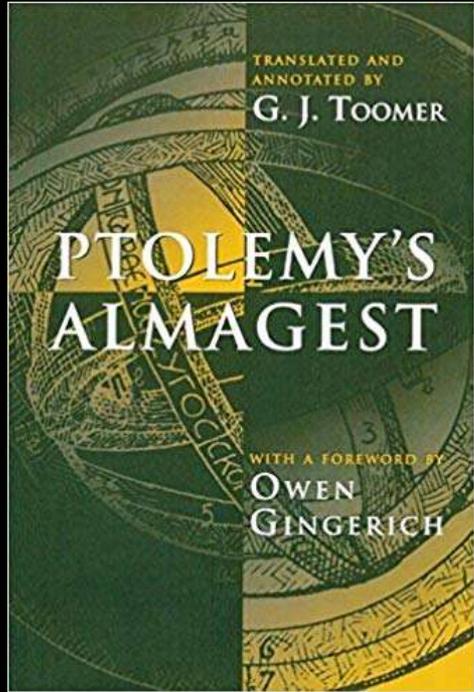


# Roman Natural Philosophy – Celestial Imperfection

Claudius Ptolemy AD 100 – c. 170

Heavenly bodies did, in fact, not move with perfect circular motions: they speeded up, slowed down, and in the cases of the planets even stopped and reversed their motions.

In his great astronomical work, *Almagest*, Ptolemy presented a complete system of mathematical constructions that accounted successfully for the observed motion of each heavenly body but complicated with many more types of cycles



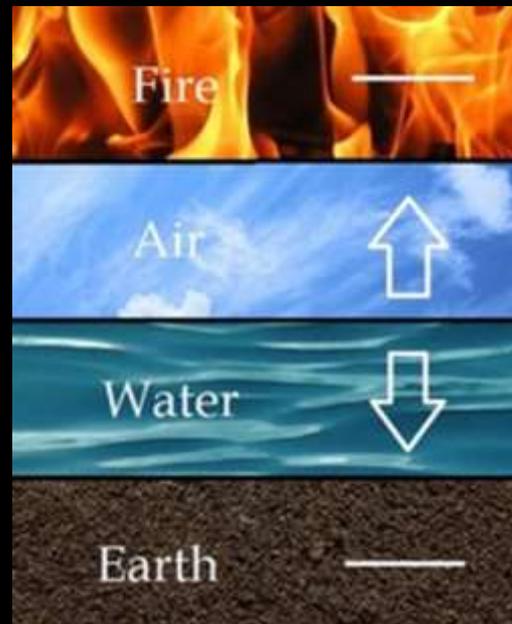
# Aristotle's Cosmos and Medieval "Exact Sciences"

- Medieval investigations of the cosmos that were largely mathematical – Astronomy, optics, mechanics - clocks
- Astrology – the practical application of astronomy but tensions with theology



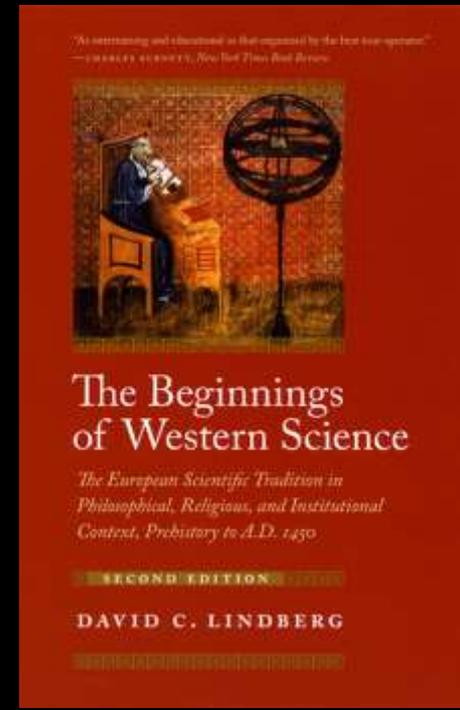
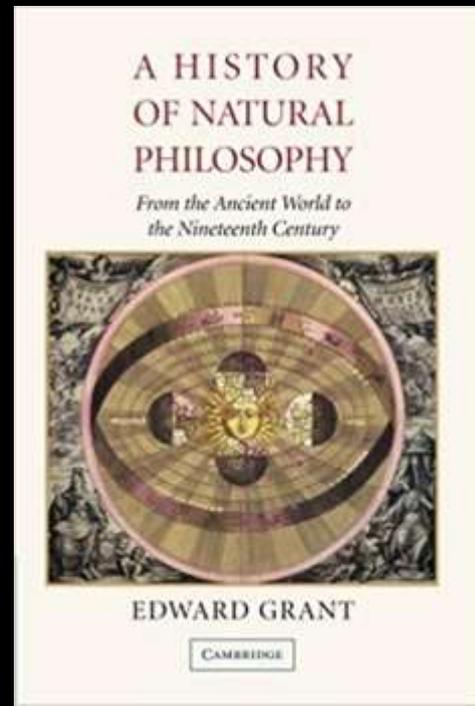
# Medieval Natural Philosophy and Aristotelian Natural Philosophy

- Little experimental science (All knowledge contained in Aristotle's books which "scholars" study = "Scholasticism")
- Alchemy - all matter was composed of four elements: earth, air, fire, and water. With the right combination of elements any substance on earth might be formed. This included precious metals as well as elixirs to cure disease and prolong life. Alchemists believed that the "transmutation" of one substance into another was possible. (the Dark Arts)



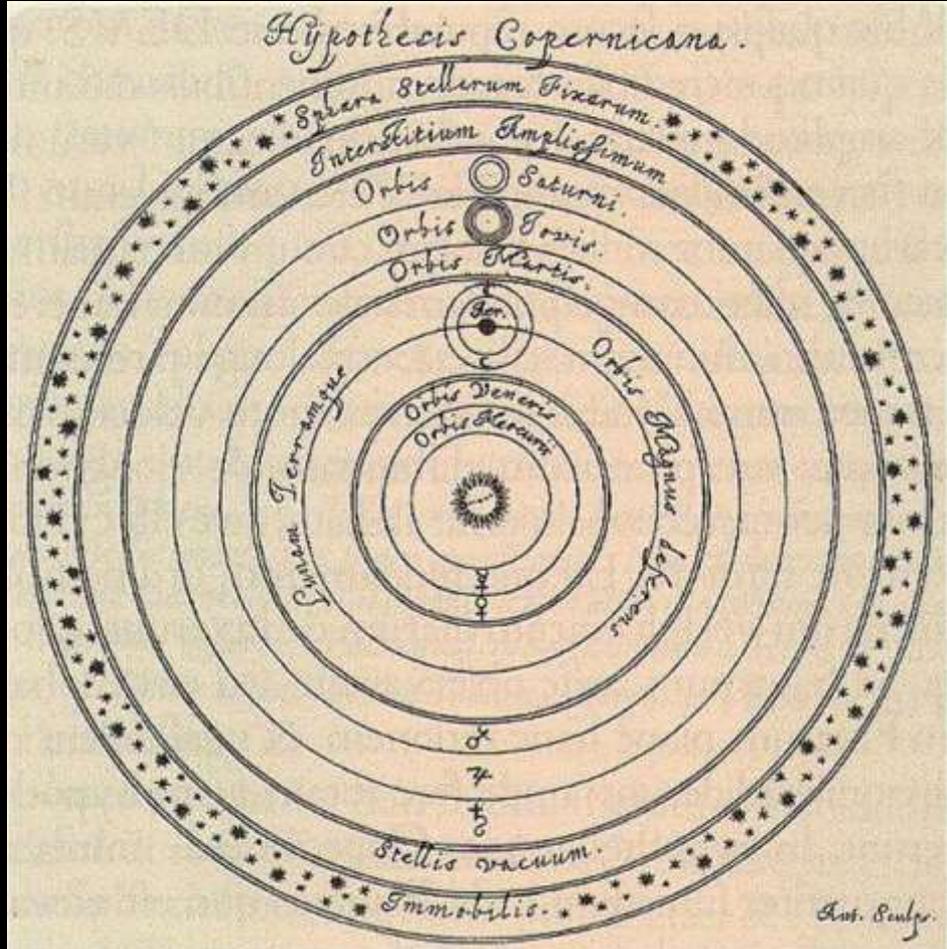
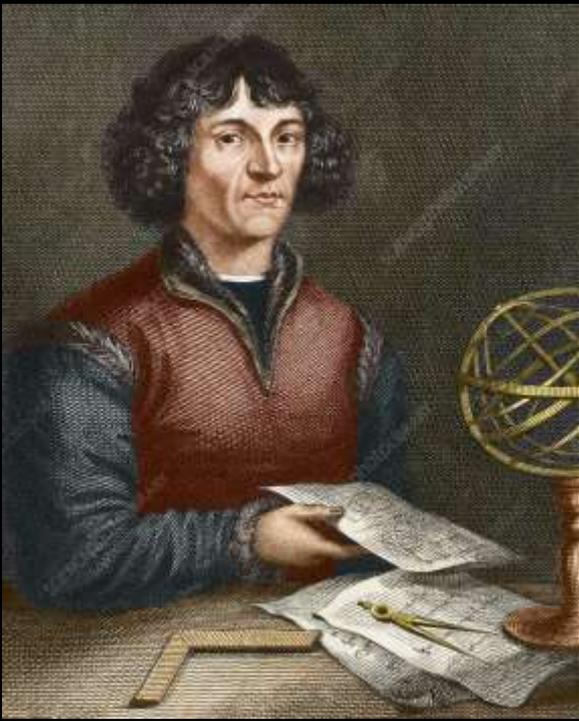
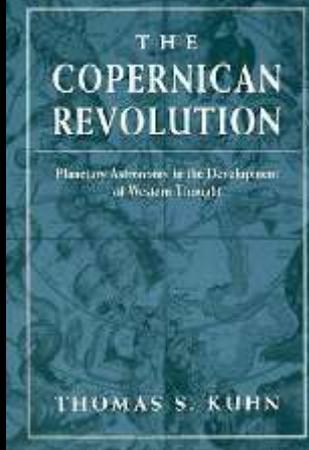
# Scholasticism, Theology, and Late Medieval Natural Philosophy

- “Scholastic Philosophy” the most common approach to natural philosophy was to comment on, or to dispute questions arising from, the natural philosophy works of Aristotle, especially his *Physics*, *On the Heavens*, etc.
- Problems with Aristotle – Prime Mover vs. Christian God – no intervention, not omnipotent
- Problematic tendency in Natural Philosophy – the tendency to restrict analysis to causal principles discoverable through the exercise of human observation and reason, without regard for the teachings of biblical revelation or church tradition.
- “Divine or supernatural causation was never denied, but it was placed...outside the province of natural philosophy.” Lindberg



# Fixing Ptolemy - The Scientific Revolution 1543-1687

- Nicolaus Copernicus (1473–1543)
- The Heliocentric Cosmos – simplifies the Ptolemaic Cosmos
- *De revolutionibus orbium coelestium* (On the Revolutions of the Heavenly Spheres) 1543

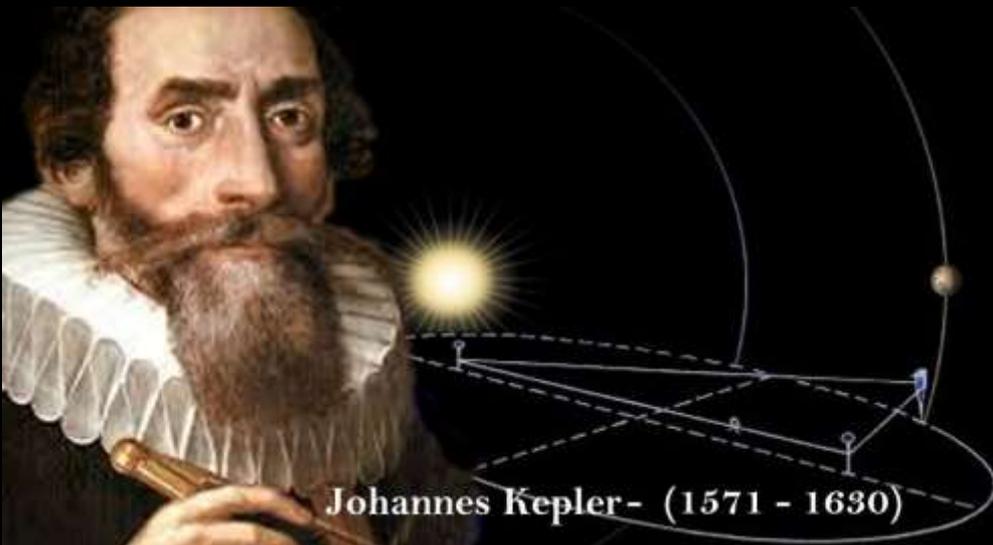


# Fixing Copernicus

Johannes Kepler (1571–1630)

*Astronomia nova* (The New Astronomy, Based upon Causes, or Celestial Physics, Treated by Means of Commentaries on the Motions of the Star Mars) 1609

- Kepler described his new astronomy as "celestial physics" as "a supplement" to Aristotle's *On the Heavens*, treated astronomy as part of natural philosophy (terrestrial physics).
- The Sun is the engine that moves the planets
- The planets move in elliptical orbits with the Sun at one focus



Johannes Kepler - (1571 - 1630)

ASTRONOMIA NOVA  
ΑΙΤΙΟΛΟΓΗΤΟΣ,  
SEV  
PHYSICA COELESTIS,  
tradita commentariis  
DE MOTIBVS STELLÆ  
MARTIS,  
Ex observationibus G. V.  
TYCHONIS BRAHE:

Jussu & sumptibus  
RVDOLPHI II.  
ROMANORVM  
IMPERATORIS &c:



Plurium annorum pertinaci studio  
elaborata Pragæ,

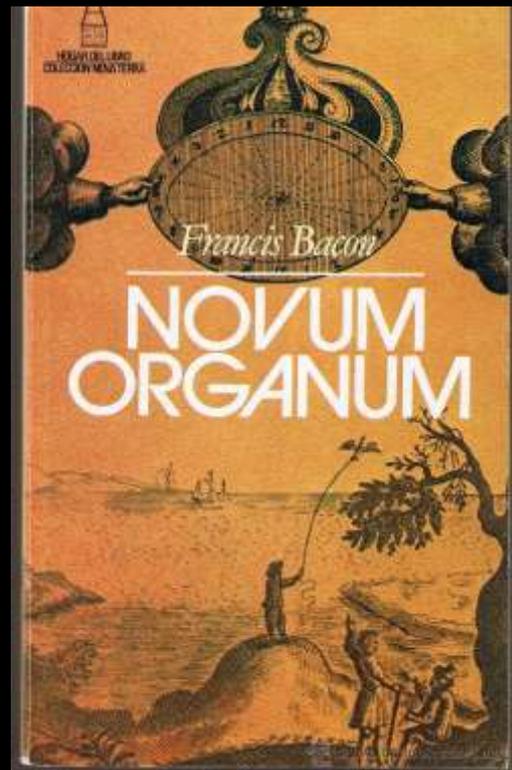
A S<sup>c</sup>. C<sup>æ</sup>. M<sup>o</sup>. S<sup>c</sup>. Mathematico  
JOANNE KEPLERO,

Cum ejusdem C<sup>æ</sup>. M<sup>o</sup>. privilegio speciali  
ANNO MDCX Dionysianæ clc Idc ix.

# Experimental Natural Philosophy “take the question to nature”

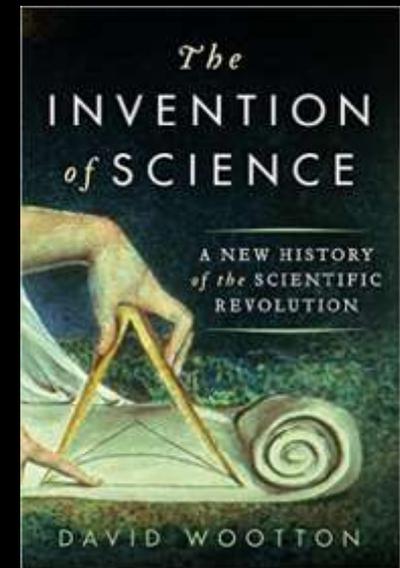
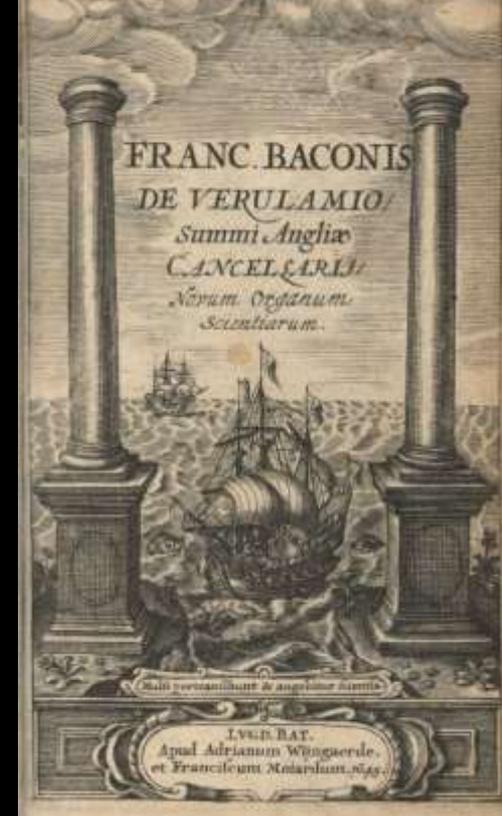
Francis Bacon 1561 – 1626

- an English philosopher, statesman, lawyer, and pioneer of what is later called the scientific method (not Bacon’s term)
- The *Novum Organum, sive indicia vera de Interpretatione Naturae* (“New tool, or true directions concerning the interpretation of nature”) published in 1620. The title is a reference to Aristotle's work *Organon* (Tool)
- Bacon argued that Scholastic natural philosophy was too focused on what Aristotle said in books rather than physical nature itself, and the natural philosopher should instead “take the question to nature” and learn by direct observation and experiments
- Bacon's emphasis on the use of artificial experiments to provide additional observances of a phenomenon is one reason that he is often considered "the Father of the Experimental Philosophy“
- Apart from the "laws of nature" themselves, the causes relevant to natural philosophy are only efficient causes and material causes i.e. matter and motion (not formal or final)



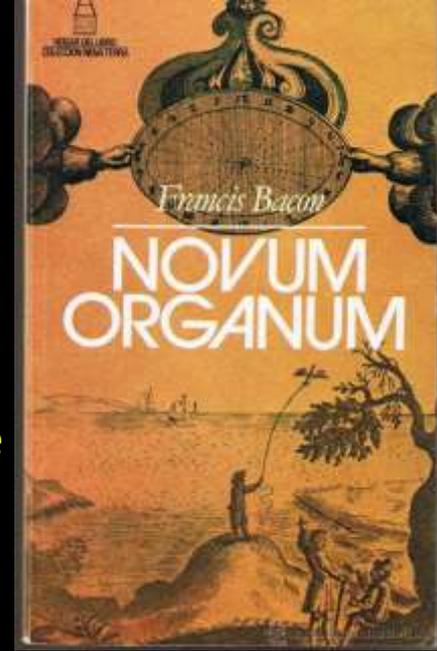
# Bacon – Discovery, Scientific Travelers, and The Scientific Revolution 1543-1687

- The title page of *Novum Organum* depicts a galleon passing between the mythical Pillars of Hercules that stand either side of the Strait of Gibraltar, marking the exit from the well-charted waters of the Mediterranean into the Atlantic Ocean.
- Bacon hopes that empirical investigation will, similarly, smash the old ideas of natural philosophy and lead to greater understanding of the world and heavens.
- Discovery of New Knowledge is possible
- Wootton (2015) “The dramatic success of the new science in explaining the natural world promotes this “natural philosophy” as an independent authority challenging the old theological philosophy and construct a new world view.”
- “Experience is a great teacher” changes from “learn from the past” to “experience can actually teach you that what other people know is wrong.”
- “It is experience in this sense – experience as a path to discovery – that was scarcely recognized before the discovery of America.”
- The Historians Debate - Were medieval and early modern natural philosophy continuous with each other or discontinuous?

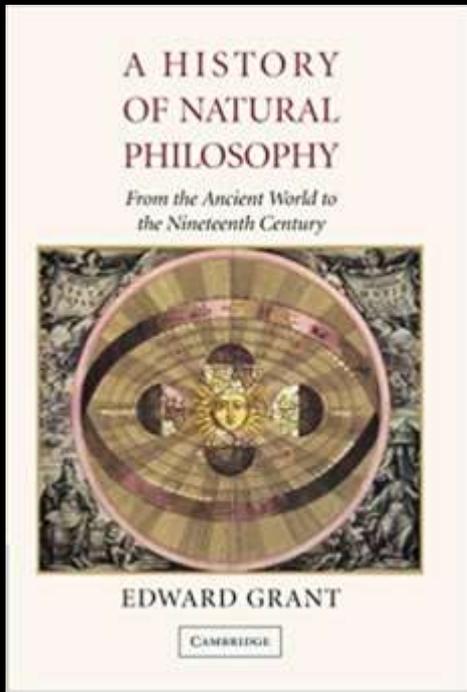


# Bacon – Natural Philosophy, Mathematics, and the Exact Sciences

- Grant (2007) “Francis Bacon gave voice to the most significant problem that confronted natural philosophy in its lengthy history from Aristotle onwards: What is the proper relationship between natural philosophy and mathematics and the exact sciences?”
- Bacon was convinced that the “Great Mother of the Sciences” natural philosophy had to embody within itself all of the exact sciences because it “nourished within itself a multiplicity of specialized sciences, such as physics, chemistry, biology, and their numerous subdivisions”
- Natural Philosophy had to merge with mathematics and the Exact Sciences - Astronomy, Optics, Mechanics



1620

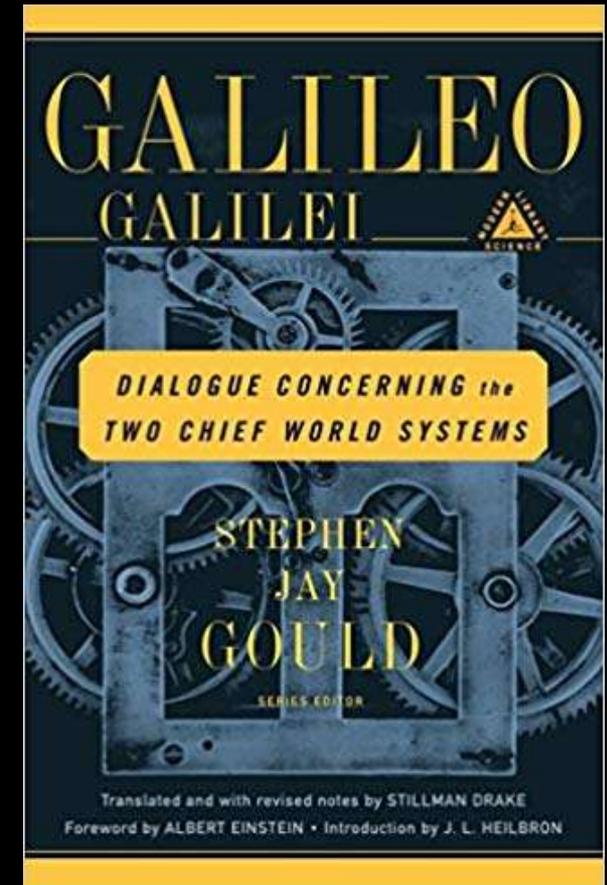
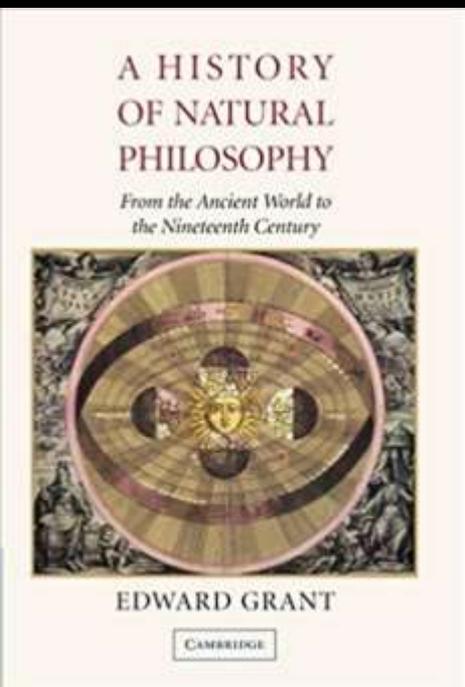


## De-throning Aristotle – Galileo 1564-1642

In his *Dialogue Concerning the Two Chief World Systems, Ptolemaic and Copernican* (1632), Galileo (1564–1642) attacked the cosmology of Aristotle and the technical astronomy of Ptolemy

He de-throned the Aristotelian physical categories of the one celestial element and four terrestrial elements (fire, air, water and earth) and their differential directional natures of motion (circular, up and down).

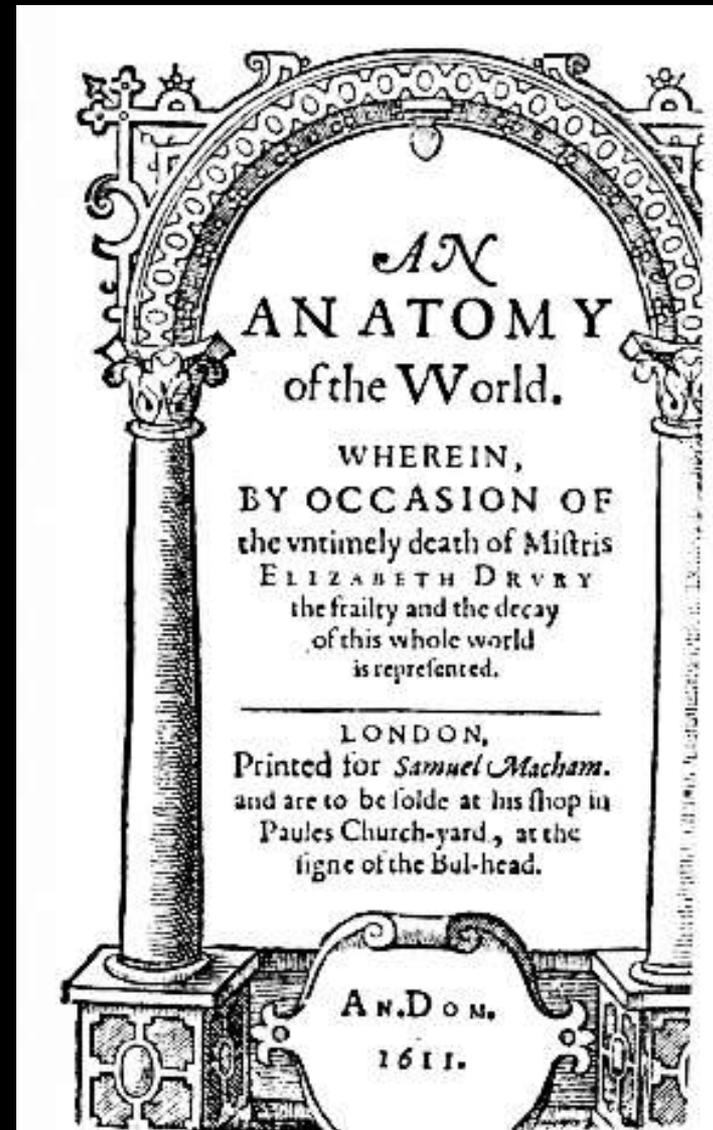
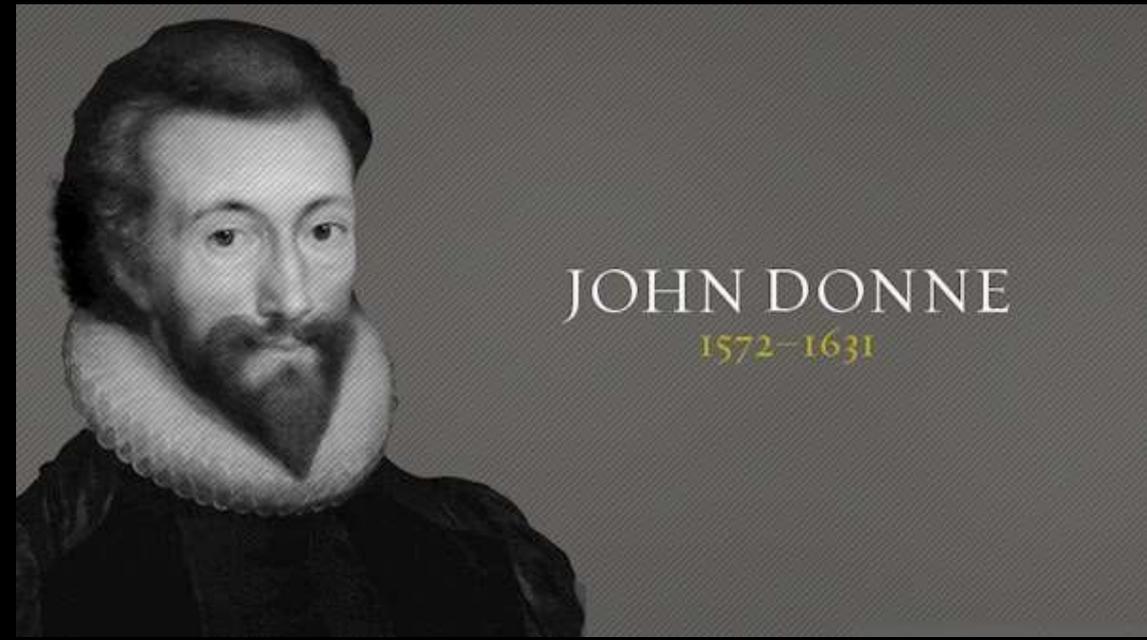
In their place he left only one element, corporeal matter, and a different way of describing the properties and motions of matter in terms of the mathematics



# An Anatomy of the World 1611

John Donne

And new philosophy calls all in doubt,  
The element of fire is quite put out,  
The sun is lost, and th'earth, and no man's wit  
Can well direct him where to look for it.  
And freely men confess that this world's spent,  
When in the planets and the firmament  
They seek so many new; they see that this  
Is crumbled out again to his atomies.  
'Tis all in pieces, all coherence gone,  
All just supply, and all relation;

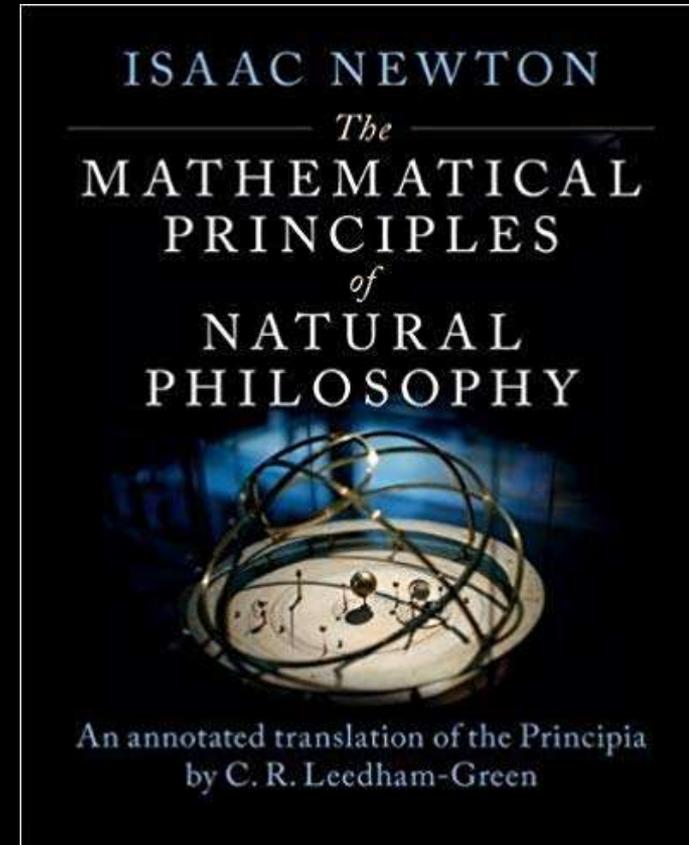


## Coherence and Relation

### Reconciling Mathematics and Natural Philosophy

Isaac Newton (1642–1727)

- *Philosophiae Naturalis Principia Mathematica* (1687), whose title translates to "Mathematical Principles of Natural Philosophy"
- Grant (2007) By the end of the 17<sup>th</sup> century, the transformation of natural philosophy was manifest in Newton's great work "the very title of which reveals that a union of mathematics and natural philosophy had already occurred."
- "The Scientific Revolution occurred because after coexisting independently for many centuries the exact sciences of optics, mechanics, and especially astronomy merged with natural philosophy in the 17th century." Grant
- "This momentous occurrence broadened the previous all-too-narrow scope of the ancient and medieval exact sciences which now, by virtue of natural philosophy, would seek physical causes for all sorts of natural phenomena, rather than being confined to mere calculation and quantification..." Grant



1687



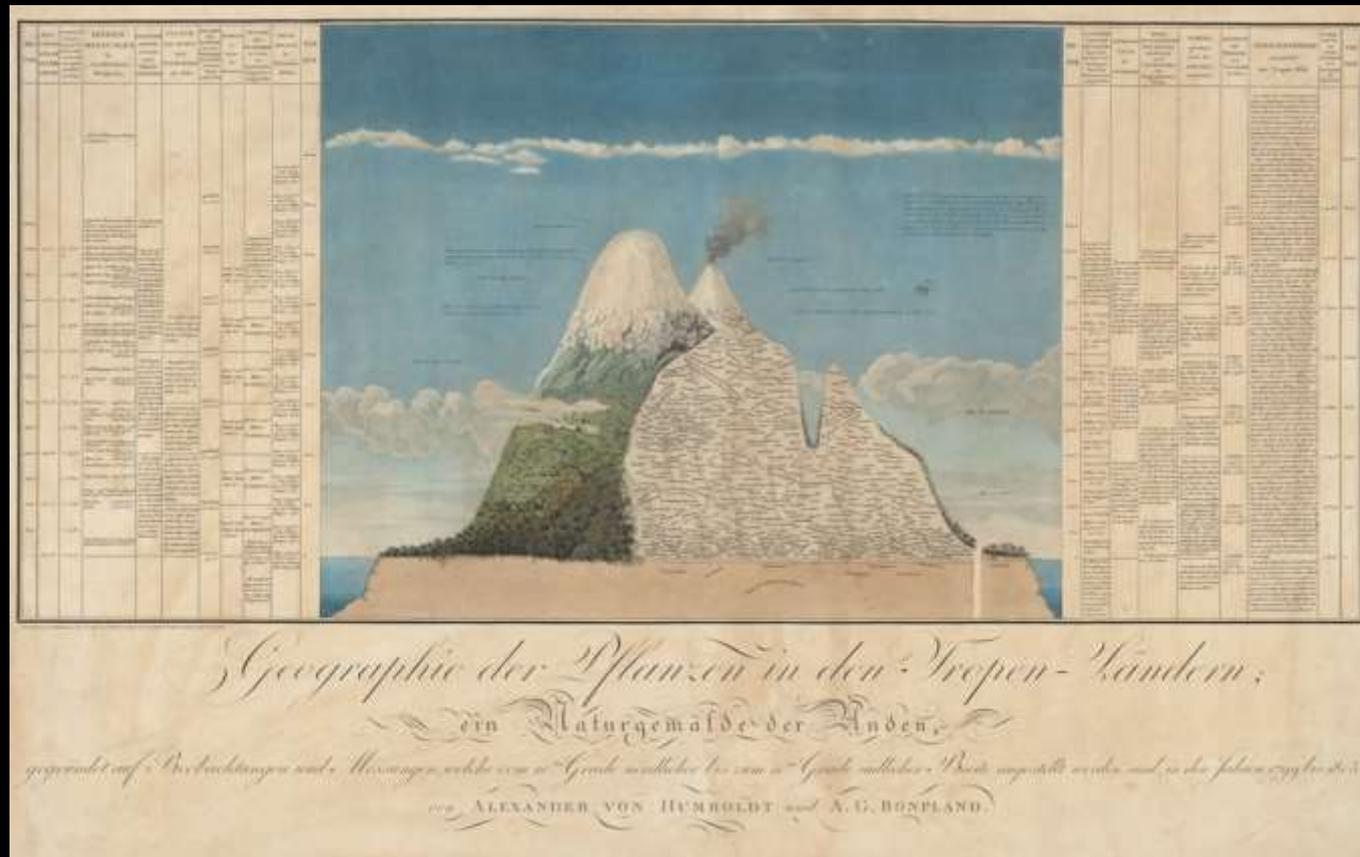
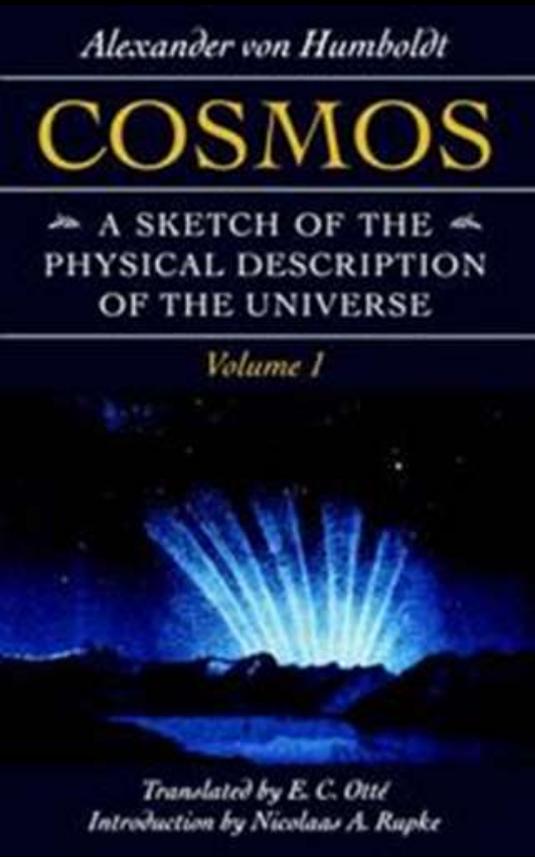
# Coherence and Relation

## Humboldtian Cosmos - A Vision of the Unity of Nature

The Cosmos is both ordered and beautiful.

*Unity in diversity, and of connection, resemblance, and order, among created things most dissimilar in their form, one fair harmonious whole...*

*Kosmos, 1845*



Applause

