Center for Environmental Research at Hornsby Bend

Austin WATER

2020 CER Lunchtime Lectures
Humboldt, Science, and The Geography of Nature

Alexander Von Humboldt (1769-1859)

In 1798, Humboldt was appointed by the King of Spain to make the first comprehensive scientific exploration of Spanish America.

Alexander von Humboldt's American expedition 1799-1804

- Expedition way
- City / Stopping place
- Spanish Viceroys 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 Havanna, 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 Havanna over Veracruz

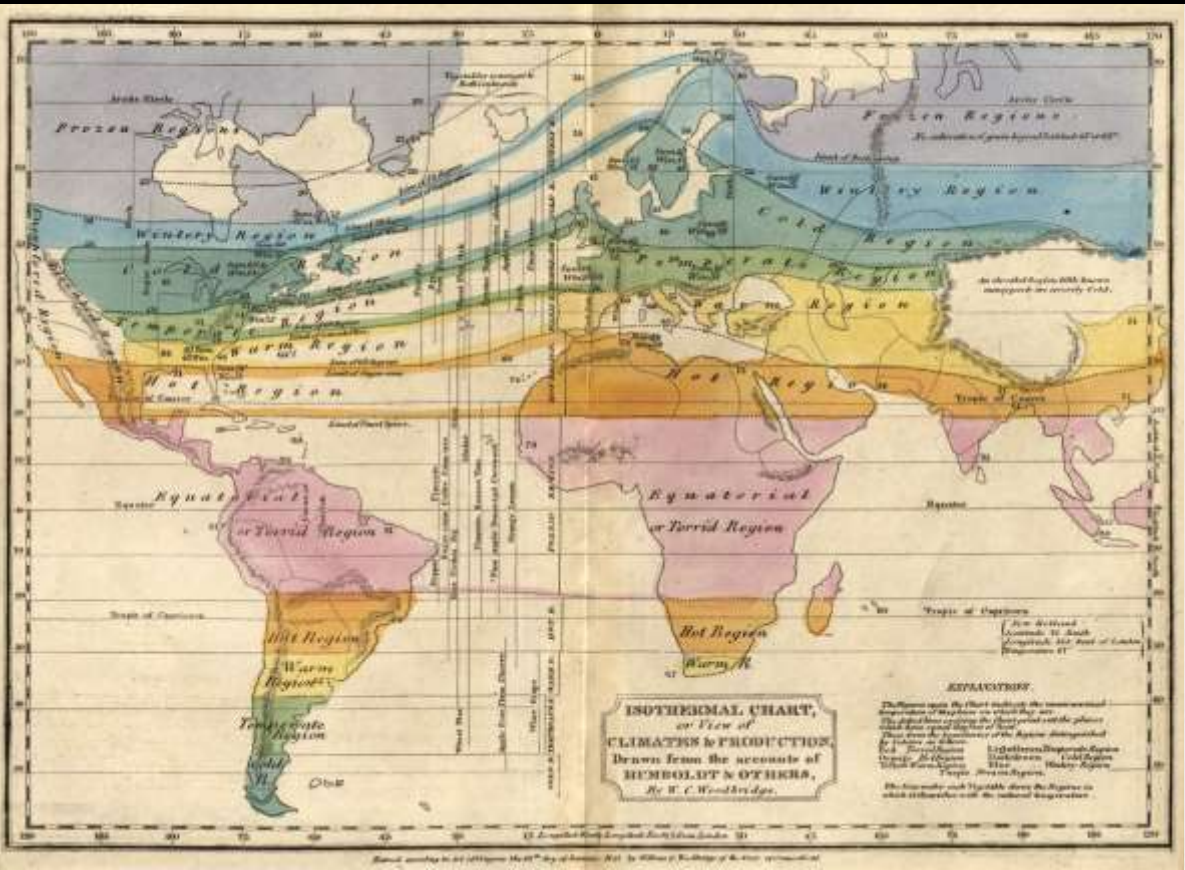
VI With the cargo ship "Concepción" to Philadelphia, Washington, with the french Frigate "La Favorite" to Bordeaux

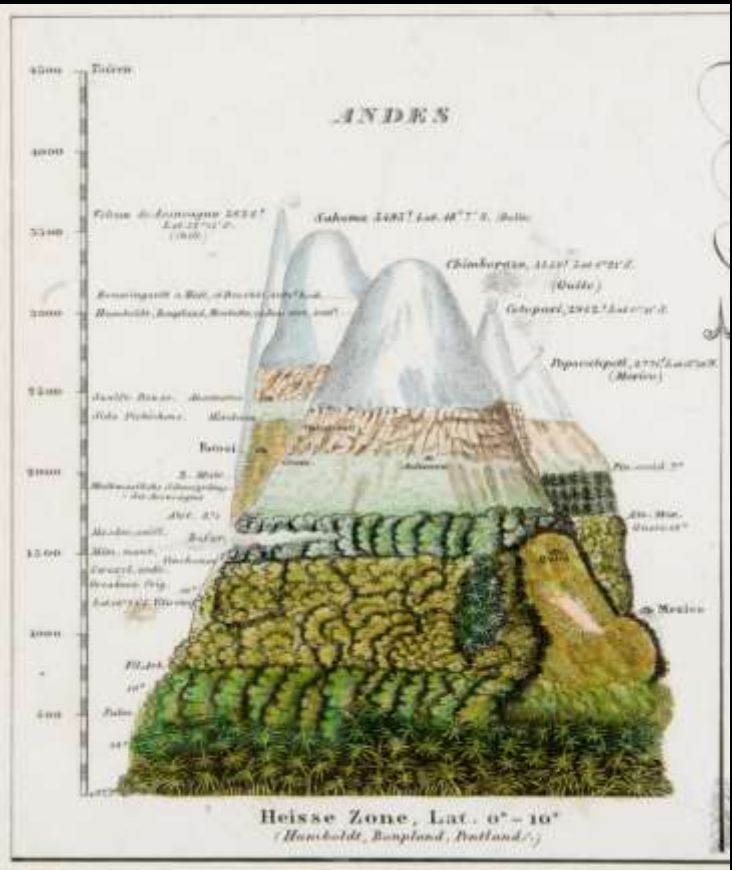
Humboldt's Vision of Nature and Science

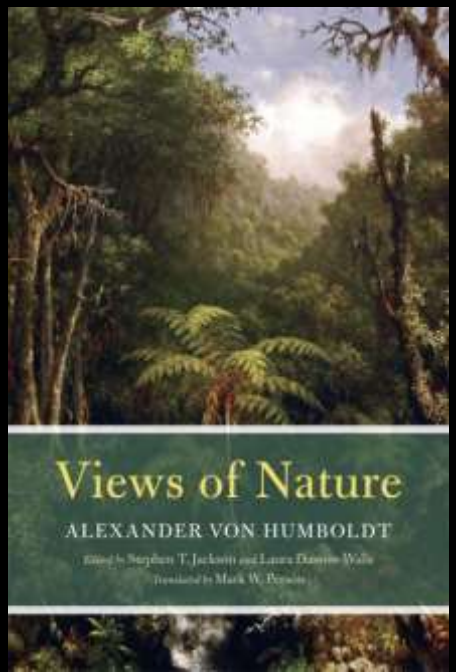
"I shall collect plants and fossils and make astronomic observations. But that's not the main purpose of my expedition – I shall try to find out how the forces of nature interact upon one another and how the geographic environment influences plant and animal life.

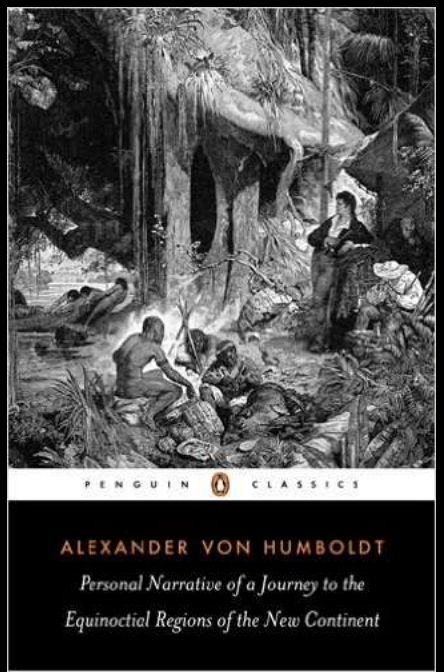
In other words, I must find out about the unity of nature."

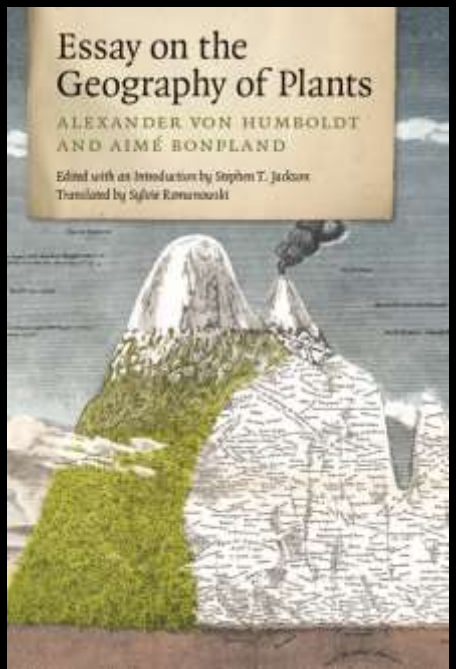
At the end of his journey, he had a new scientific vision of nature – of isotherms, ecosystems, food webs, watersheds, climate change, and complex interconnectivity.

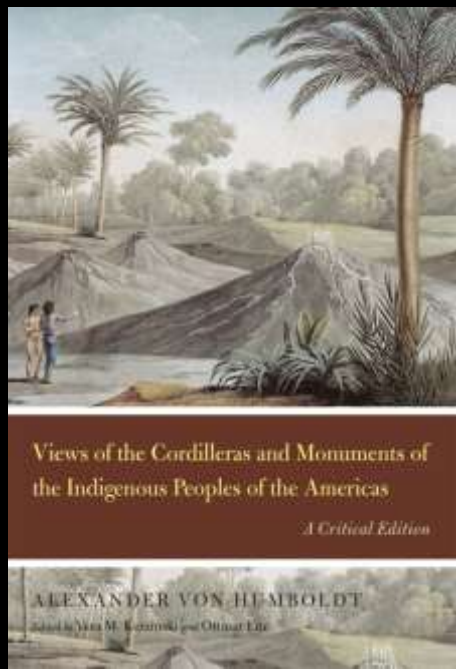




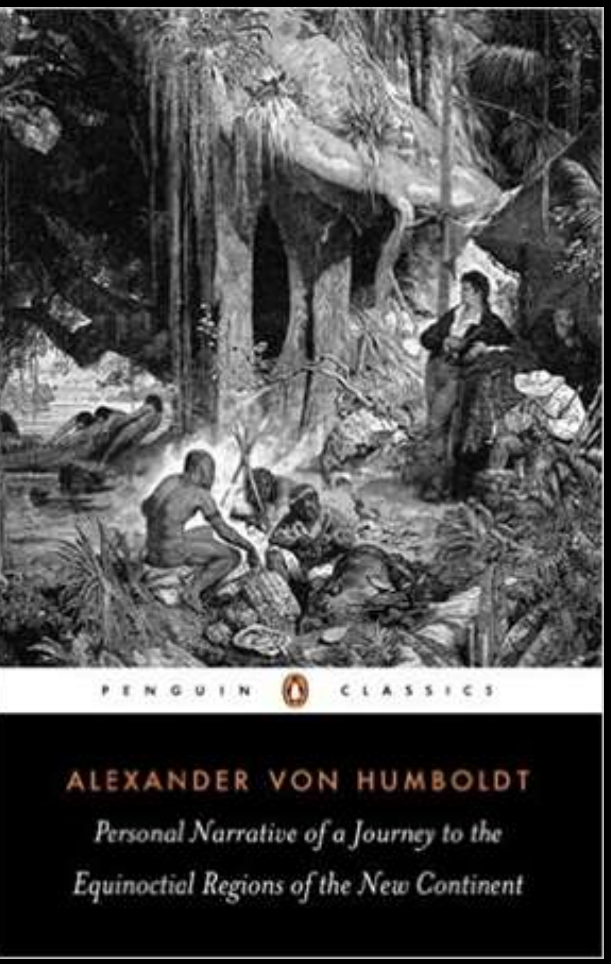

Views of Nature
ALEXANDER VON HUMBOLDT

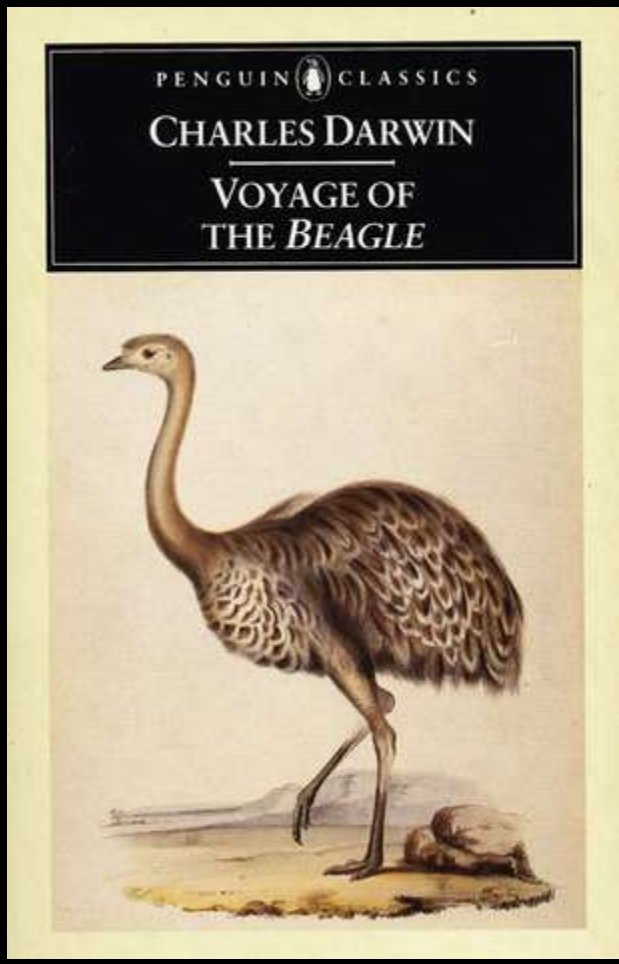

PENGUIN CLASSICS
ALEXANDER VON HUMBOLDT
Personal Narrative of a Journey to the
Equinoctial Regions of the New Continent


Essay on the
Geography of Plants
ALEXANDER VON HUMBOLDT
AND AIMÉ BONPLAND

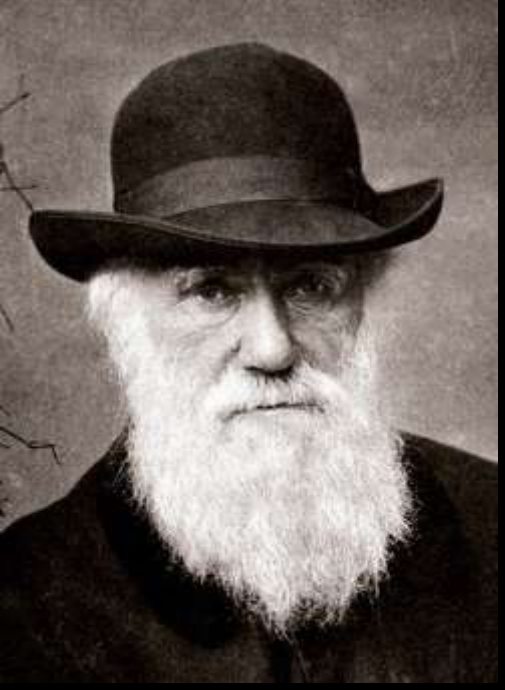

Views of the Cordilleras and Monuments of
the Indigenous Peoples of the Americas
A Critical Edition
ALEXANDER VON HUMBOLDT

Charles Darwin (1809-1882)





In the 1840s Darwin asked his best friend Joseph Hooker (1817-1911) to tell Humboldt that his "whole course of life was due to having read & re-read as a youth" Humboldt's book *Personal Narrative of a Journey to the Equinoctial Regions of the New Continent*



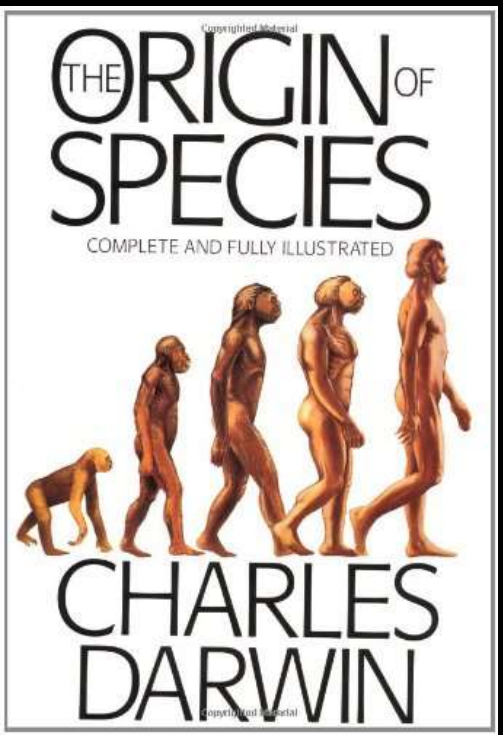
"Scientific Travelers" – Humboldt and Darwin

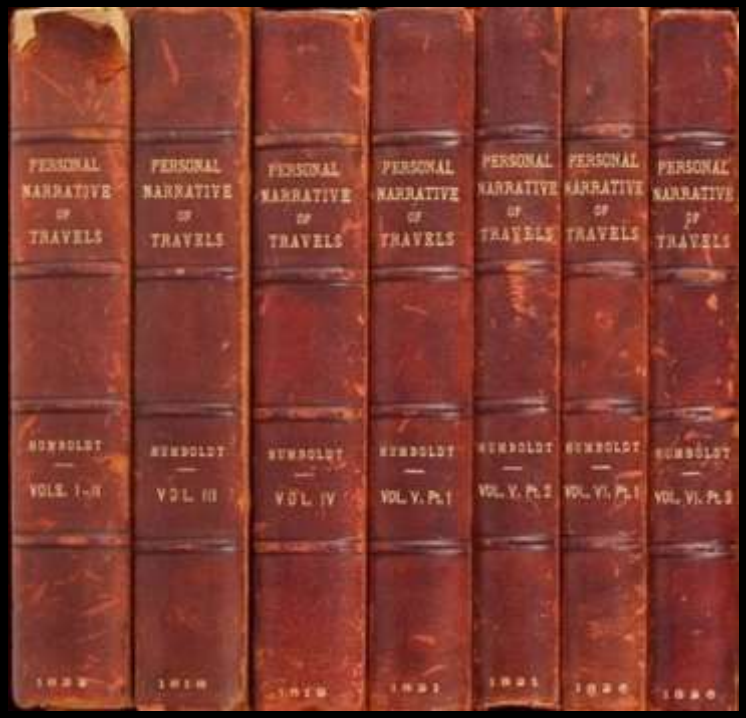
Darwin's epitaph for his hero Alexander Von Humboldt, written in a letter to his friend Hooker in 1881, the year before Darwin's own death.

"I believe that you are fully right in calling Humboldt the greatest scientific traveler who ever lived. You might truly call him the parent of a grand progeny of scientific travelers, who taken together have done much for science."

Humboldt died on May 6, 1859, six months before Darwin's *Origin of Species* was published.

"Naturalists" "Natural Philosophers" "Scientific Travelers" "Scientists"?





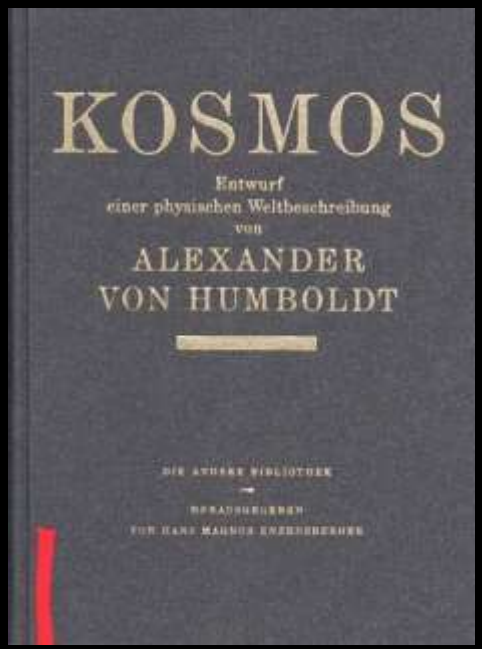
Humboldtian Science

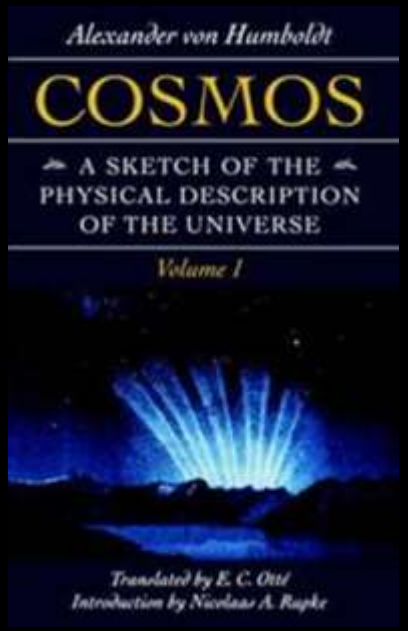
1. Explore – “Nature speaks and the scientist must go out and listen”
2. Collect – gather data for or against an idea/theory
3. Measure – widespread, accurate, collaborative
4. Connect – detect patterns that point to underlying laws
5. Cosmopolitan science – international collaboration

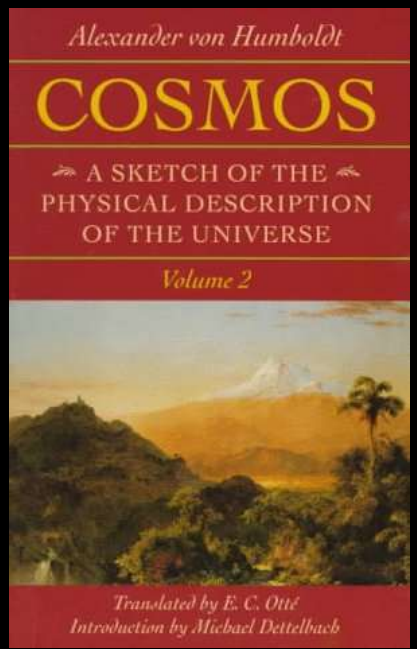
“the accurate measured study of widespread but interconnected real phenomena in order to find a definite law and a dynamic cause”

Humboldt's Cosmos "Order and Adornment"
Humans are part of Nature

- Humboldt viewed the world as what the ancient Greeks called a *kosmos* – the universe as a complex and orderly system or entity and the opposite of chaos – and he coined the modern word "cosmos" to use as the title of his final work. (five volumes between 1845 and 1862)
- For Humboldt "cosmos" signifies both the "order of the world, and adornment of this universal order."
- Order refers to the observed fact that the physical universe, independently of humans, demonstrates regularities and patterns that we can define as laws.
- Adornment refers to human imaginative perception of beauty and wonder, which is also part of the universe.





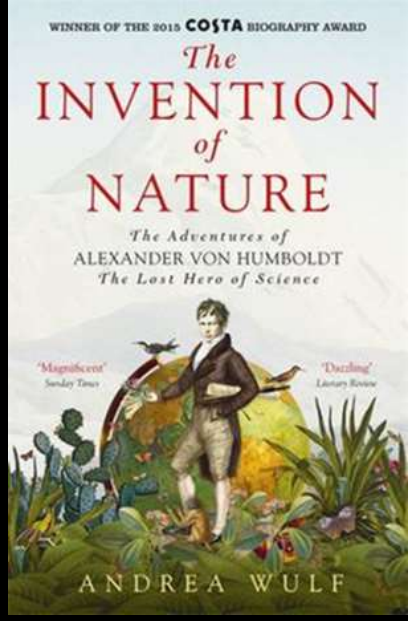


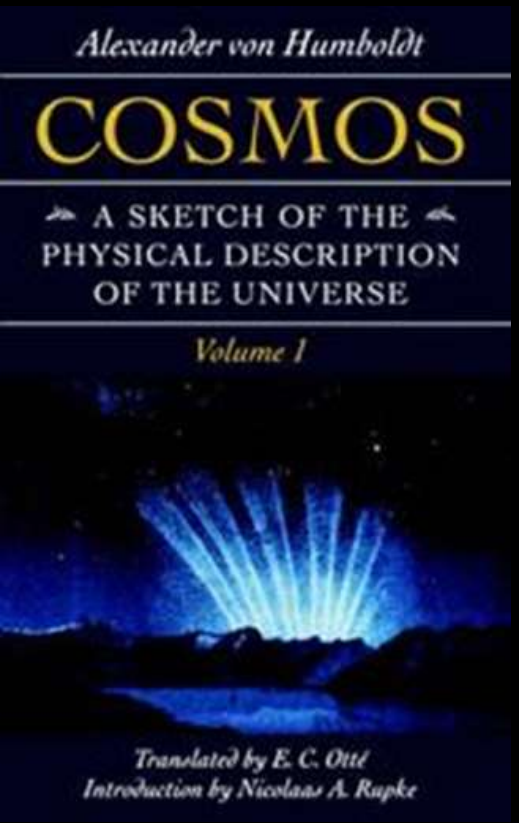
Humboldt and the Invention of Nature

Humboldt's idea of nature - as an ordered unity, as a globally complex system of interconnections, as a cosmos open to imagination and wonder, as a subject for exacting scientific study, and as an object of human mismanagement – is now a familiar concept.

But after the 19th century in the United States, Humboldt was forgotten and only rediscovered by "environmental science" in the last twenty years.

Why?





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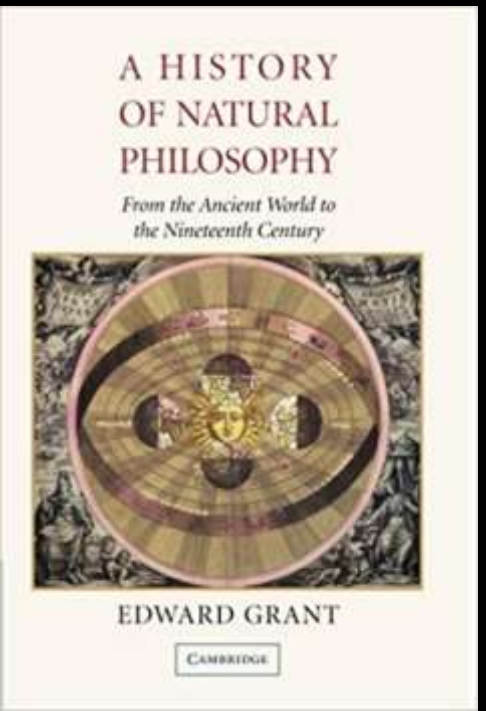
Western Culture and The Study of Nature

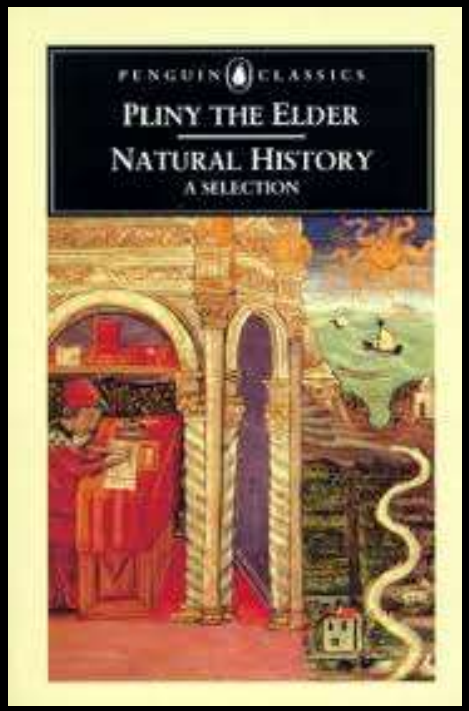
January – Natural Philosophy and the Study of Nature

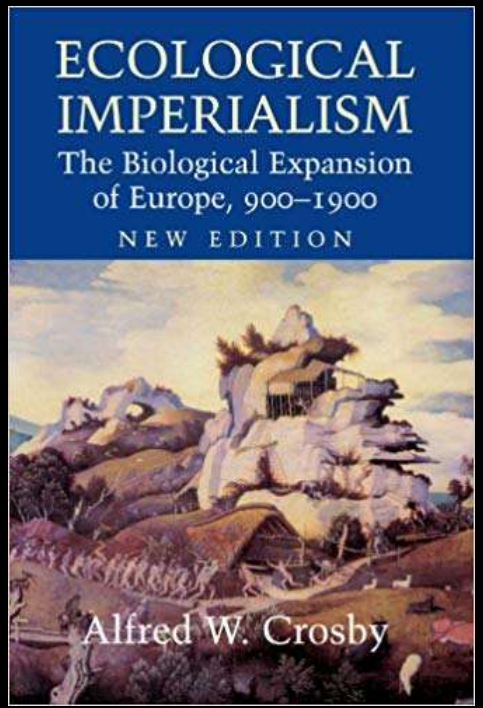
February – Natural History and the Taxonomy of Nature

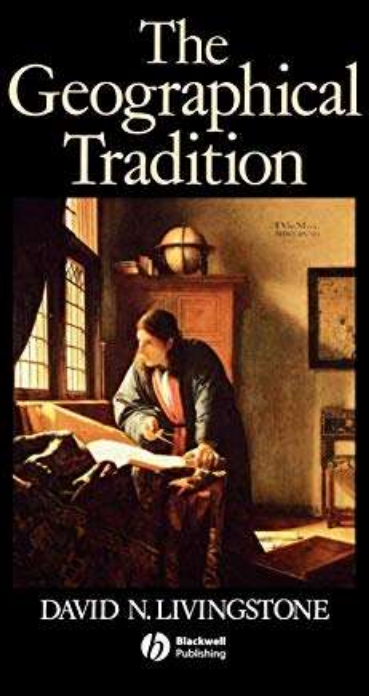
March – Ecological Imperialism and the Geography of Nature

April – Physical Geography and the Science of Nature









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Humboldt and The Science of Nature

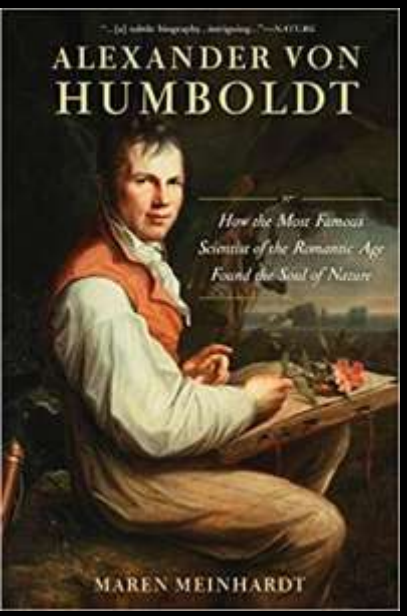
May – The Science of Nature: Humboldt and the Empirical Earth

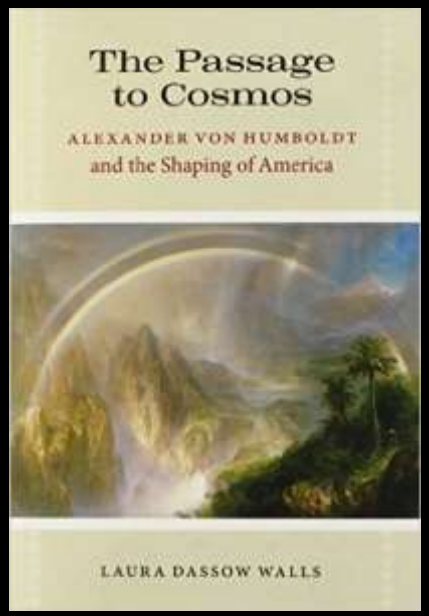
June – The Romance of Nature: Science, Imagination, and the Poets of Nature

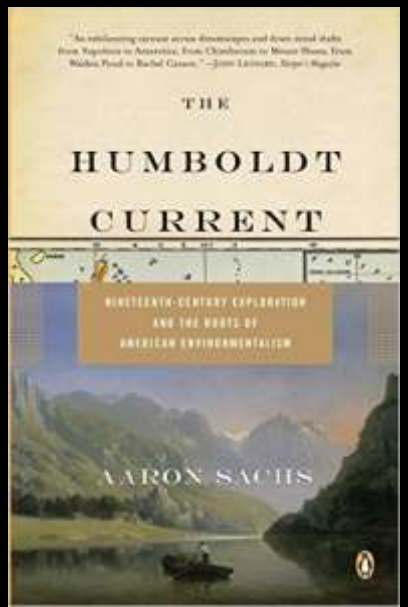
July – The Invention of Modern Nature: The Earth as a "Natural Whole"

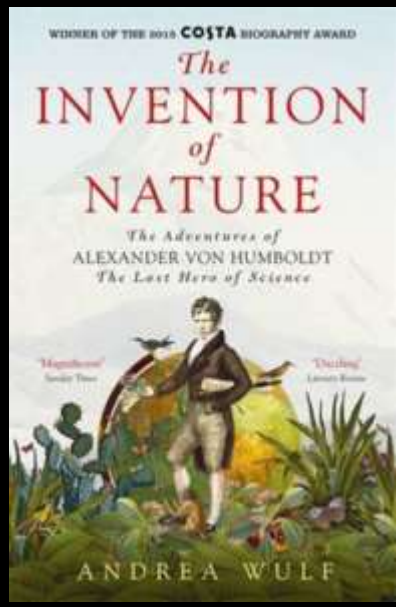
August – The Evolution of Nature: Humboldt, Darwin, and Biogeography

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









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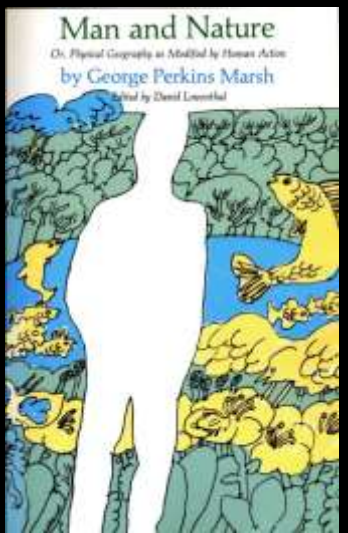
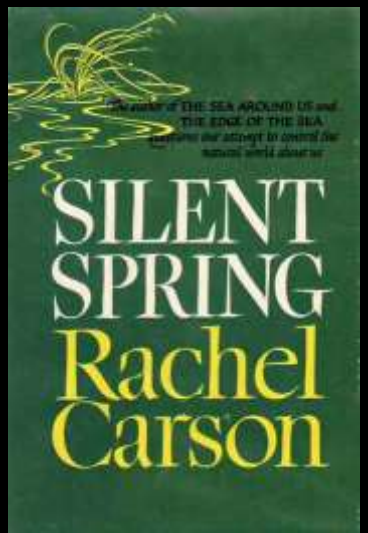
Humboldt and the Geography of Nature

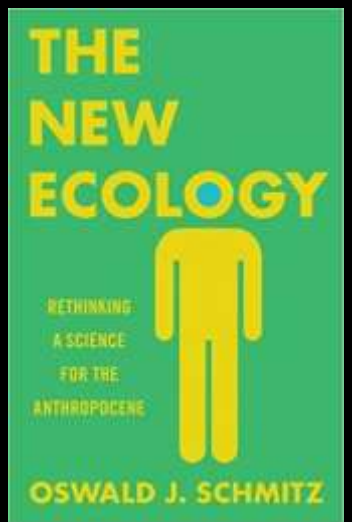
October – The Great Disruptors: Physical Geography as Modified by Human Action

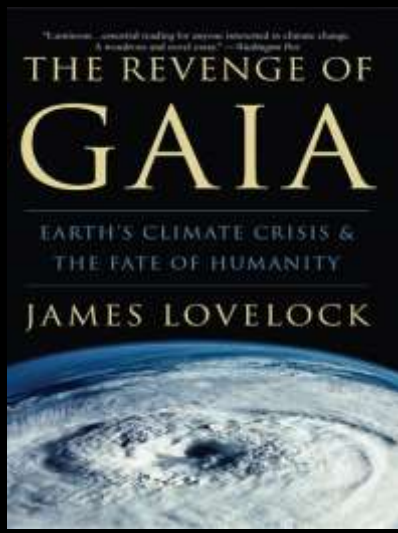
November – The Earth Managers: New Science and Environmental Change

December – The Anthropocene: Gaia and the Geography of Nature









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CER Lunchtime Lectures Online

Nature In The City Podcast

http://austineconetwork.com/nature-in-the-city/

Austin EcoNetwork

Nature in the City

City of Austin Development Services Department

Community Tree Preservation Division

2018 Nature and the American Mind

2019 The Geography of Flowing Water: Rivers, Streams, Nature, and Culture

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2020 CER Lunchtime Lectures
Humboldt, Science, and The Geography of Nature

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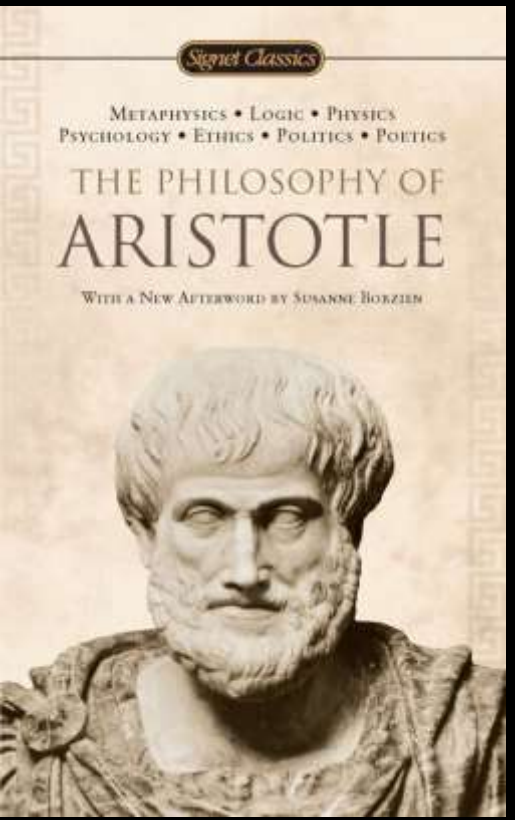
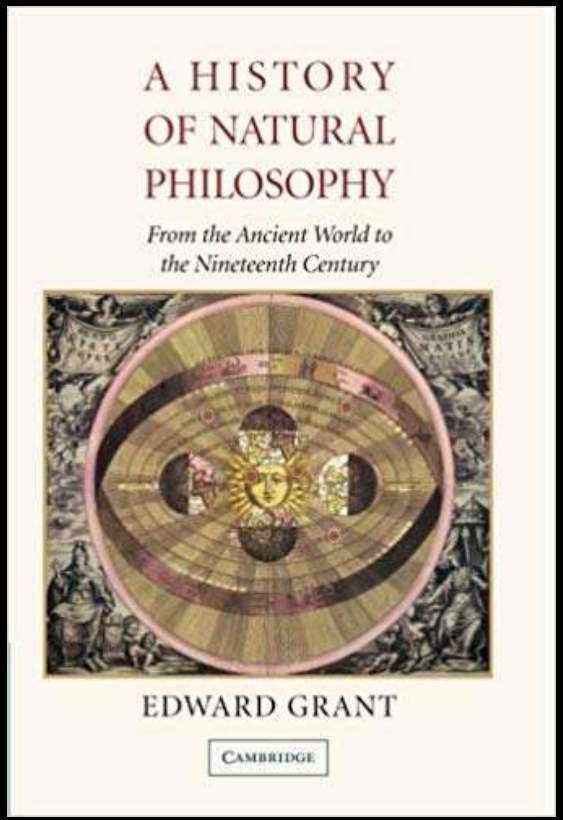
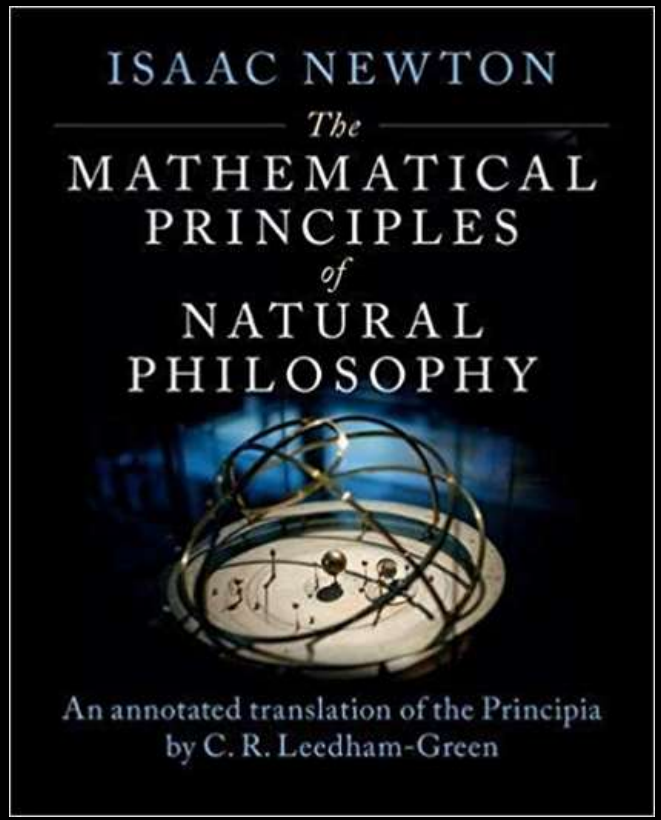
Natural Philosophy and the Concept of Nature

Kevin M. Anderson
Austin Water Center for Environmental Research

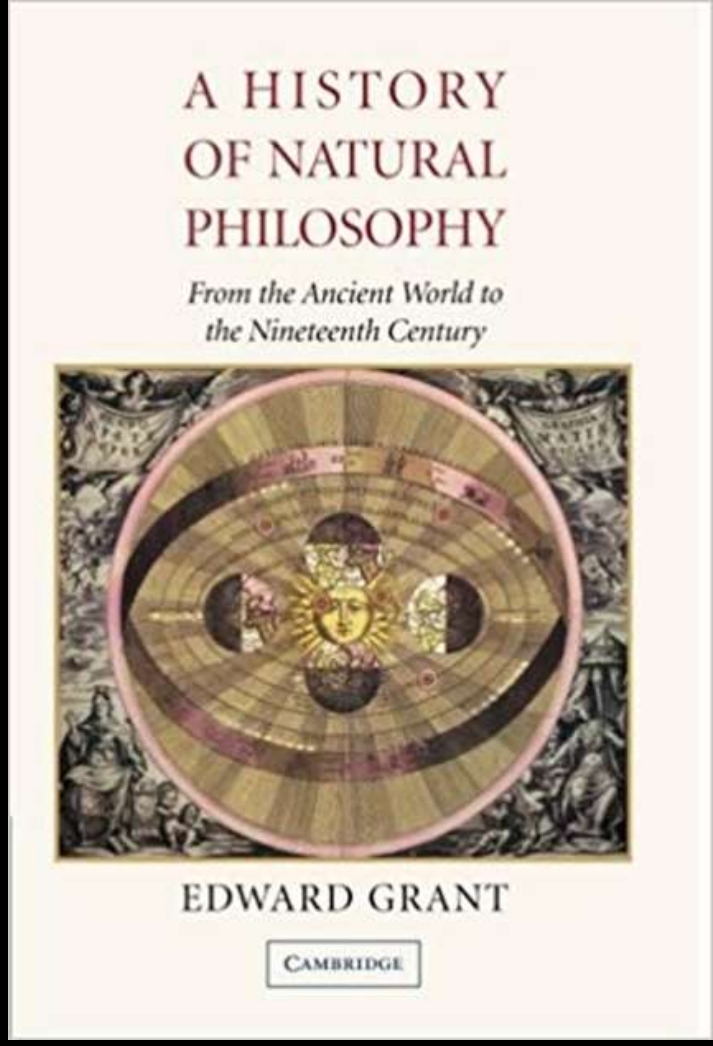






Natural Philosophy
"The Great Mother of the Sciences"

- 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.



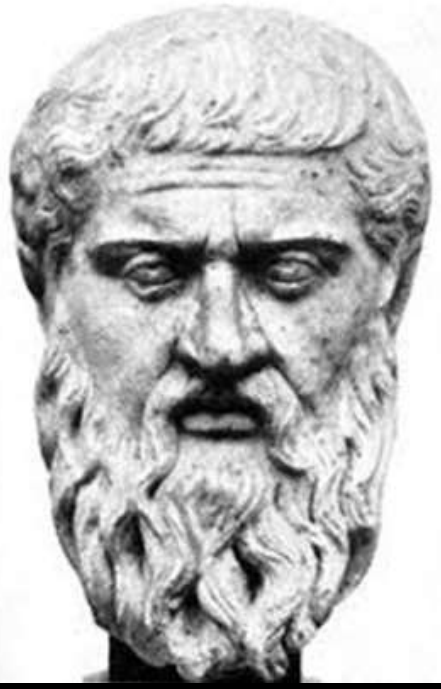
Francis Bacon – Natural Philosophy was "The Great Mother of the Sciences"

Natural Philosophy and Western Culture

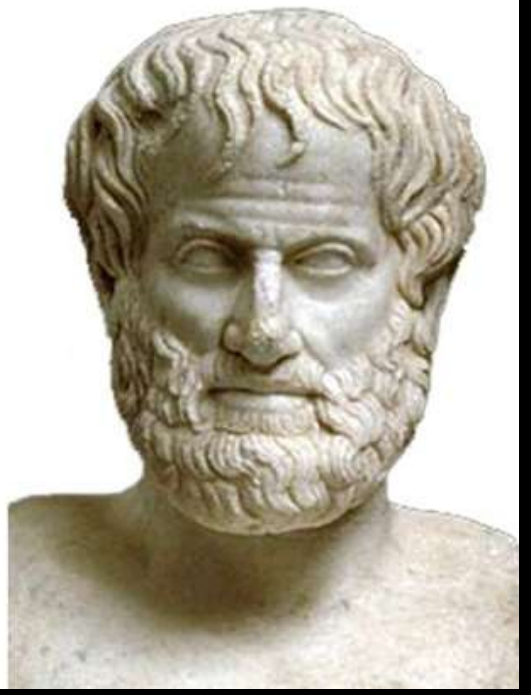
Greek Philosophers

Socrates
470-399 B.C.

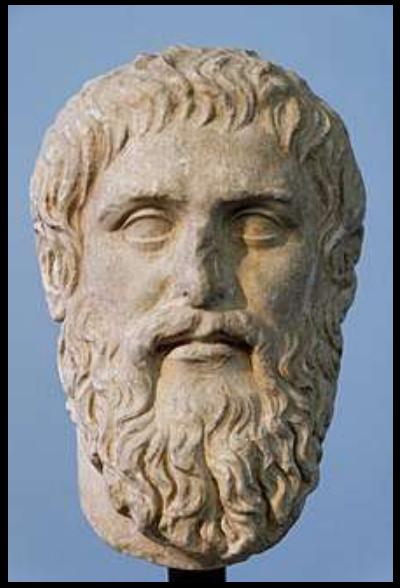
Plato
428-348 B.C.

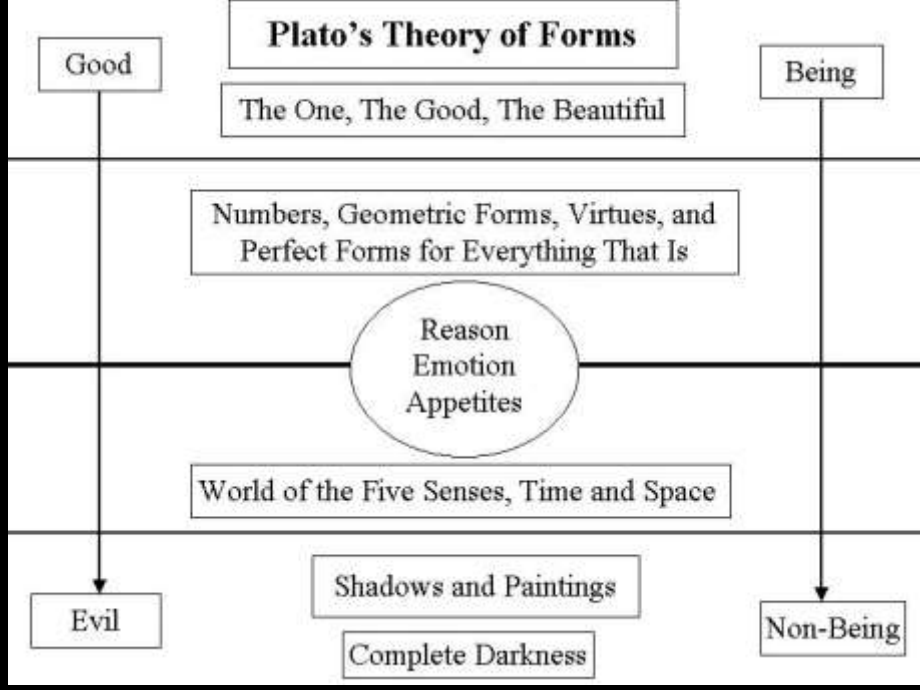


Aristotle
384-322 B.C.



Plato's Philosophy and the Study of Nature



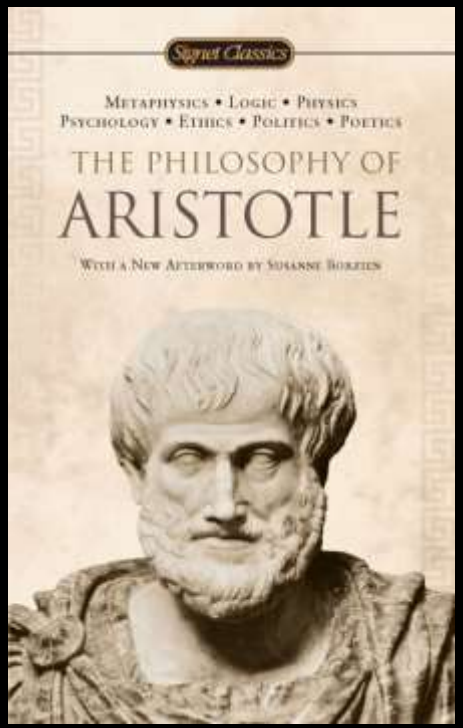


- The most fundamental distinction in Plato's philosophy is between the many observable objects that appear beautiful (good, just, unified, equal, big) and the one object that is what beauty (goodness, justice, unity) really is, from which those many beautiful (good, just, unified, equal, big) things 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.*

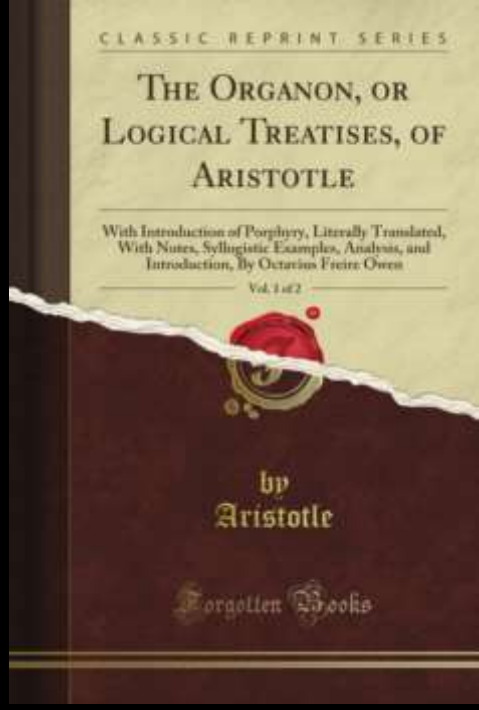


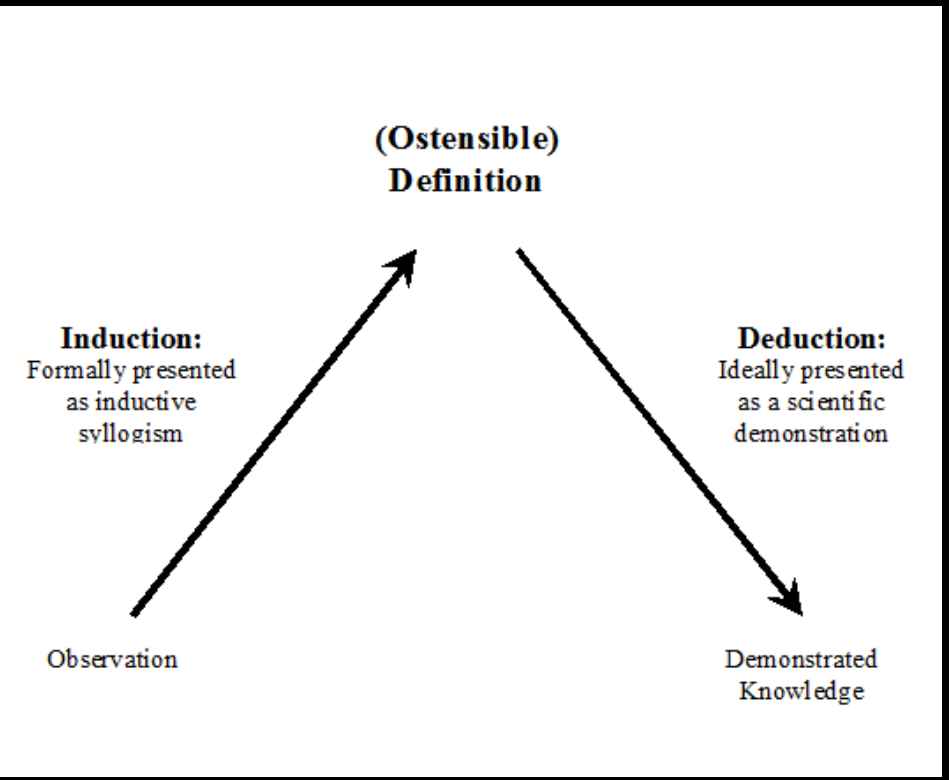
Aristotelian Logic, Knowledge, and Nature

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)

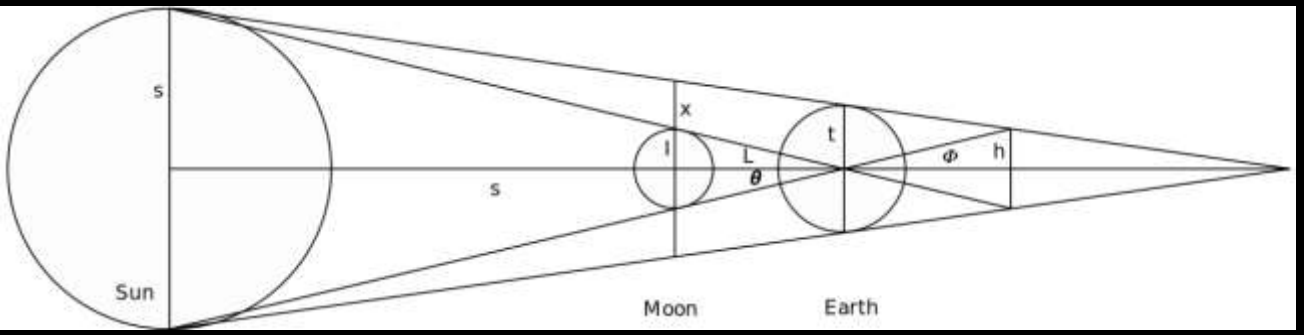
Experiential knowledge to make context-specific decisions based on one's own value/ethics (high quality tacit knowledge)

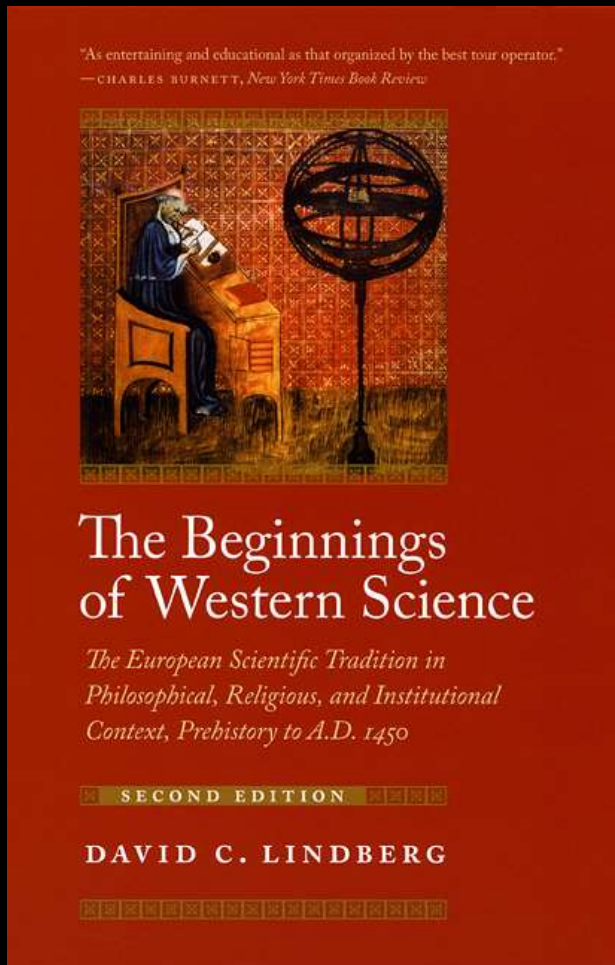
The Theoretical Sciences

- 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

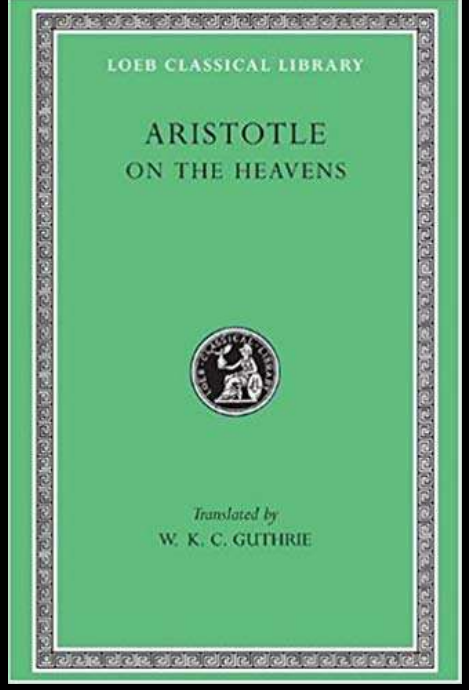
The Problem of the "Exact Sciences" and Medicine

- 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?





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

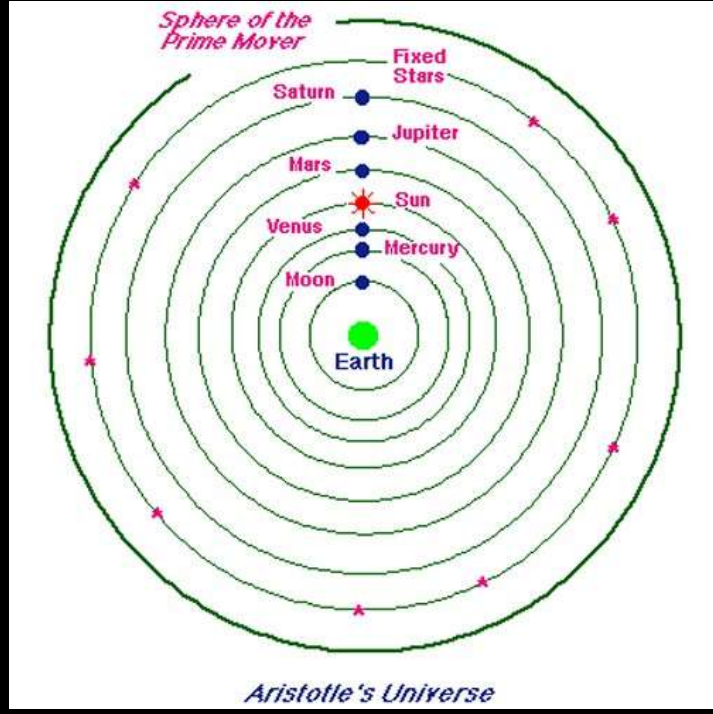
Some of these features will later cause problems for Western religion and science…

Aristotelian Cosmology (simplifed)

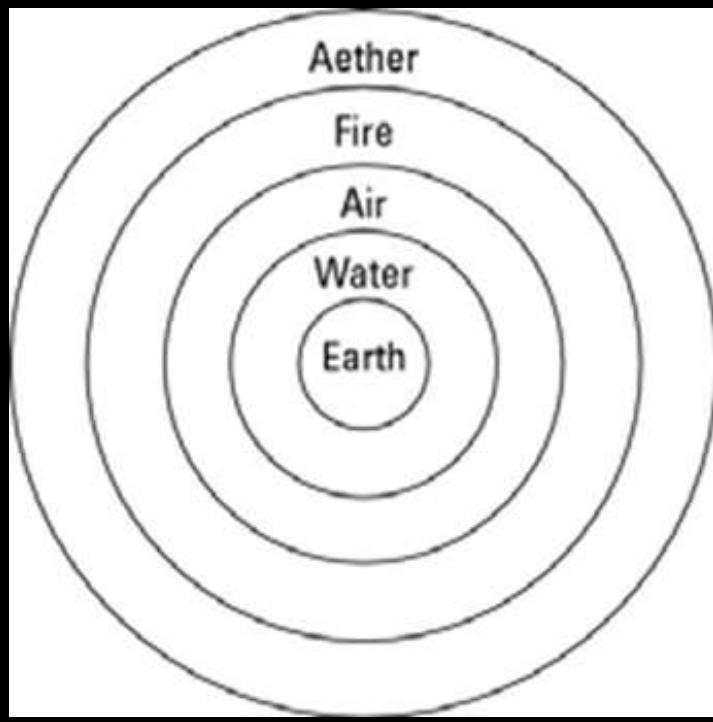
Astronomy, Theology, and Aristotle's Cosmos

- 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



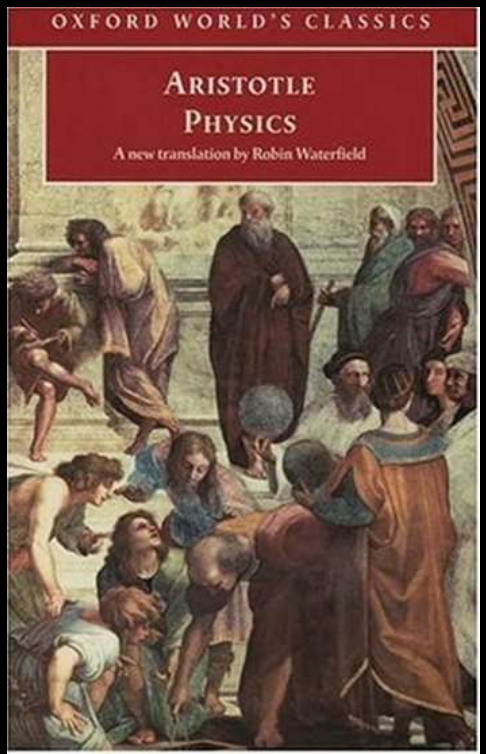
Aristotle's Universe



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

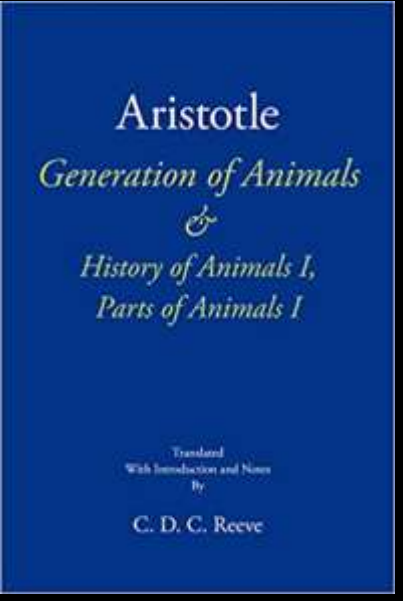


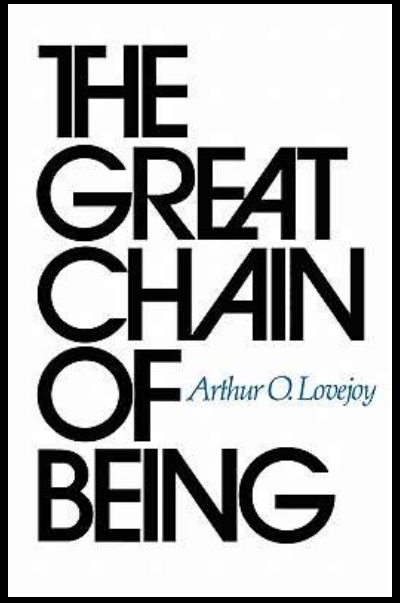
Natural Philosophy

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





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

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

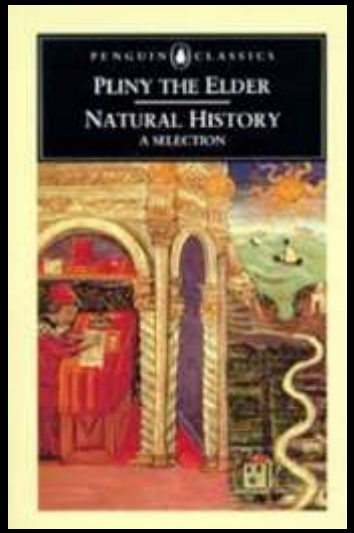
The Great Chain of Being is a graded scale of perfection rising from plants on up to humans at the tops since humans are the "rational animal"

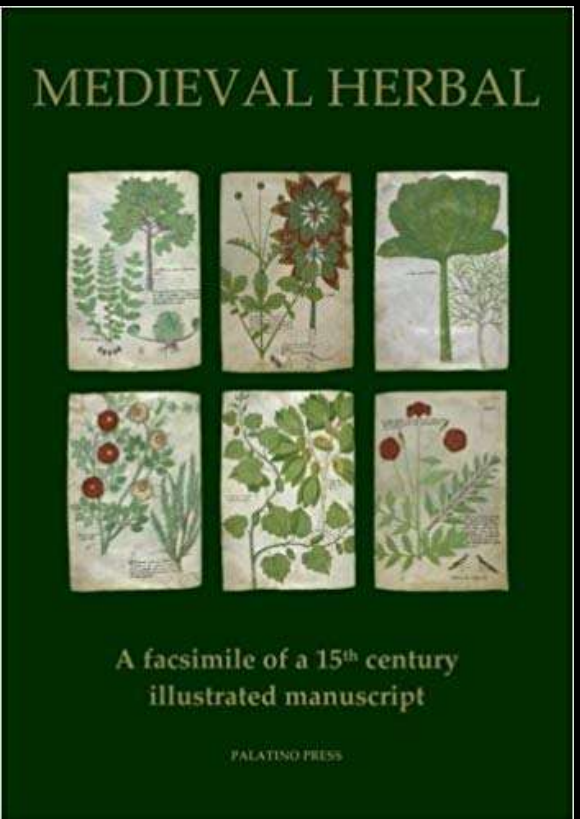
Roman and Medieval Natural Philosophy

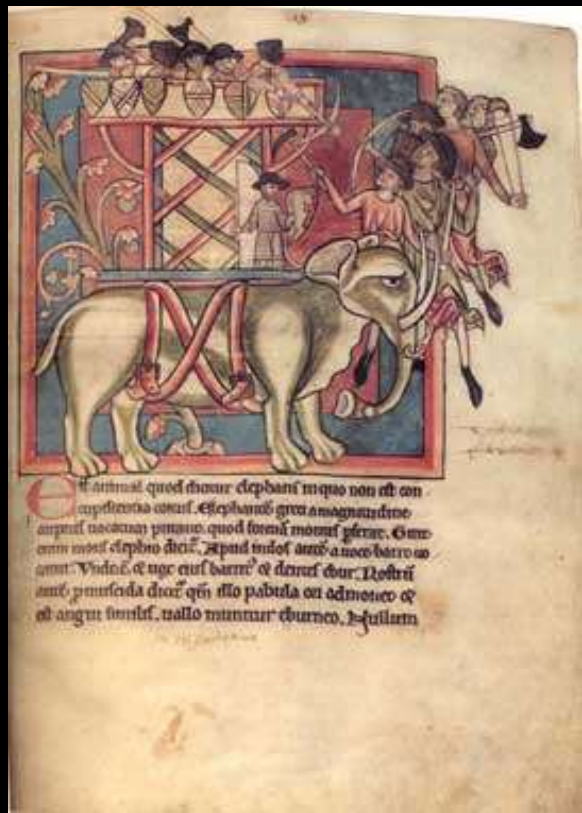
- Natural History
(Descriptive and Observational)

- Bestiaries

- Herbals - Medicine





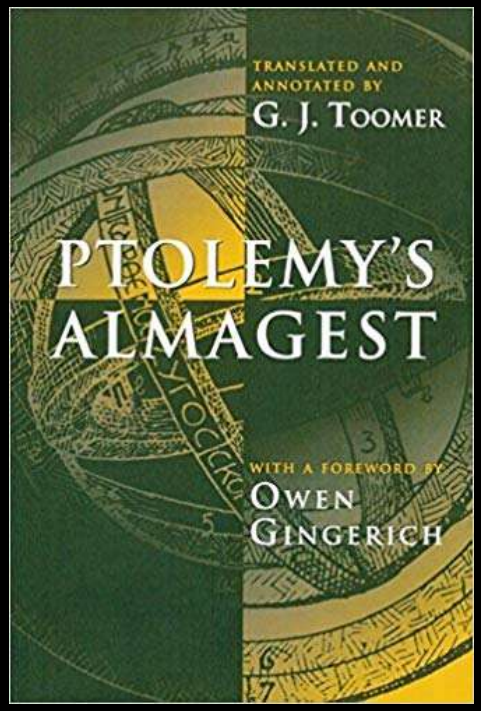


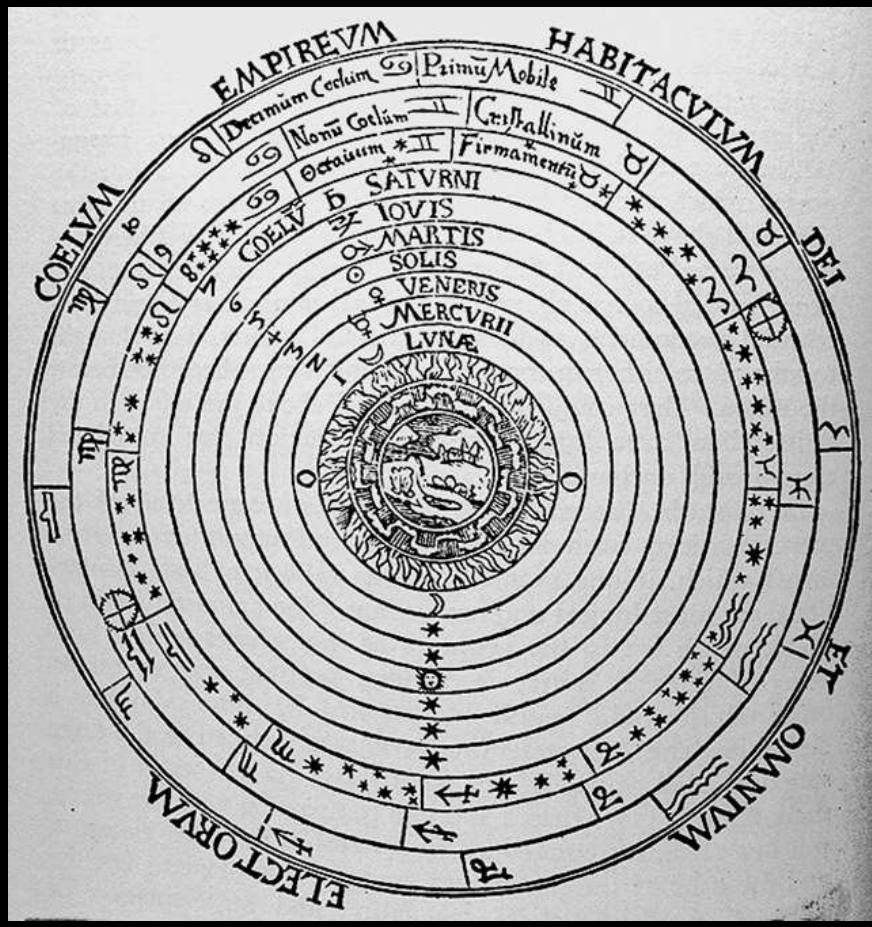
Roman Natural Philosophy – Celestial Imperfection

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.

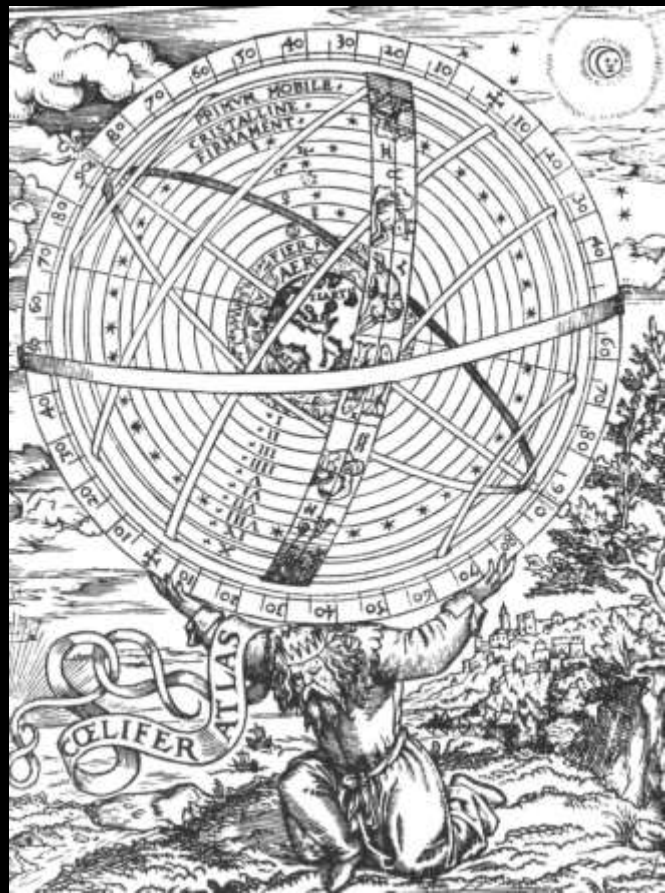
In his great astronomical work, *Almagest*, Ptolemy presented a complete system of mathematical constructions that accounted successfully for the observed motion of each heavenly body but complicated with many more types of cycles





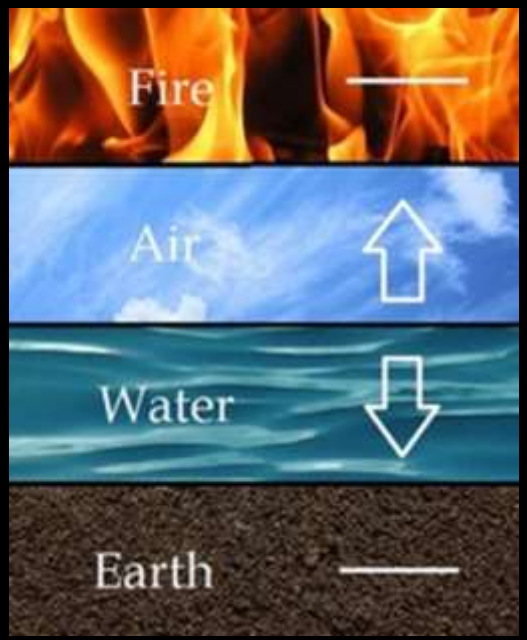
Aristotle's Cosmos and Medieval "Exact Sciences"

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



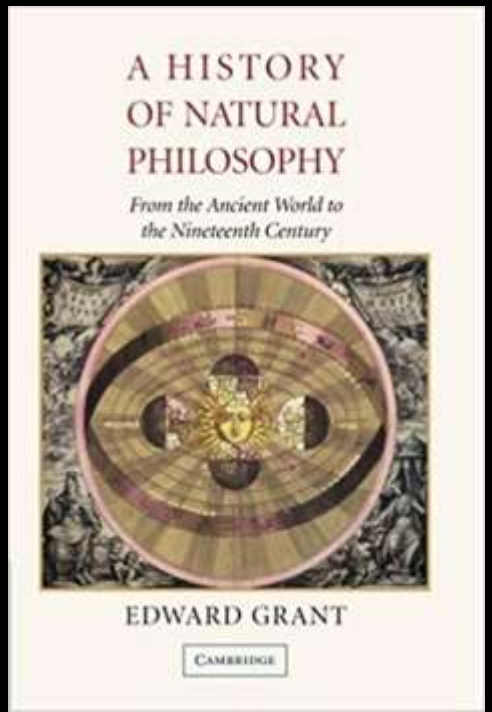
Medieval Natural Philosophy and Aristotelian Natural Philosophy

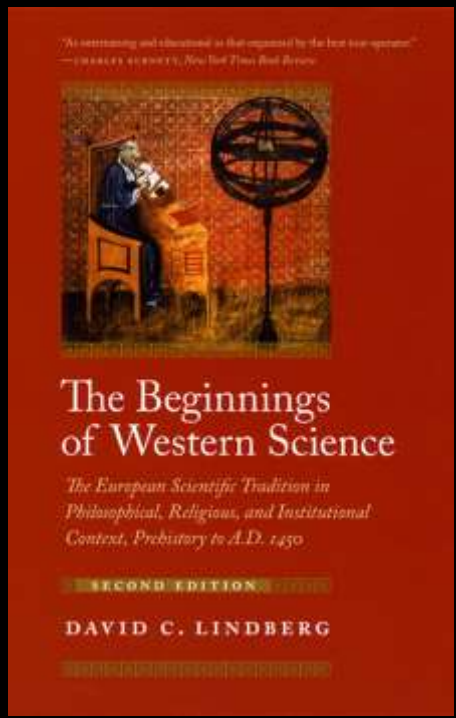
- Little experimental science (All knowledge contained in Aristotle's books which "scholars" study = "Scholasticism")
- Alchemy - all matter was composed of four elements: earth, air, fire, and water. With the right combination of elements any substance on earth might be formed. This included precious 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

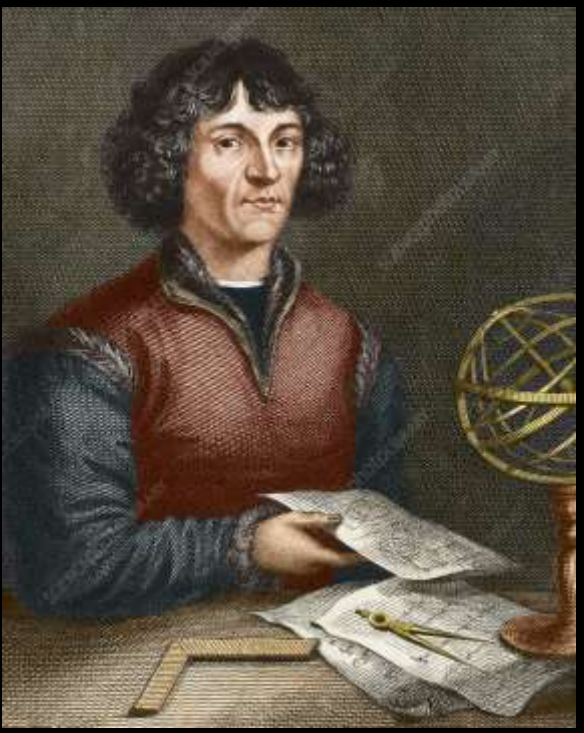
- "Scholastic Philosophy" the most common approach to natural philosophy was to comment on, or to dispute questions arising from, the natural philosophy works of Aristotle, especially his *Physics*, *On the Heavens*, etc.
- Problems with Aristotle – Prime Mover vs. Christian God – no intervention, not 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

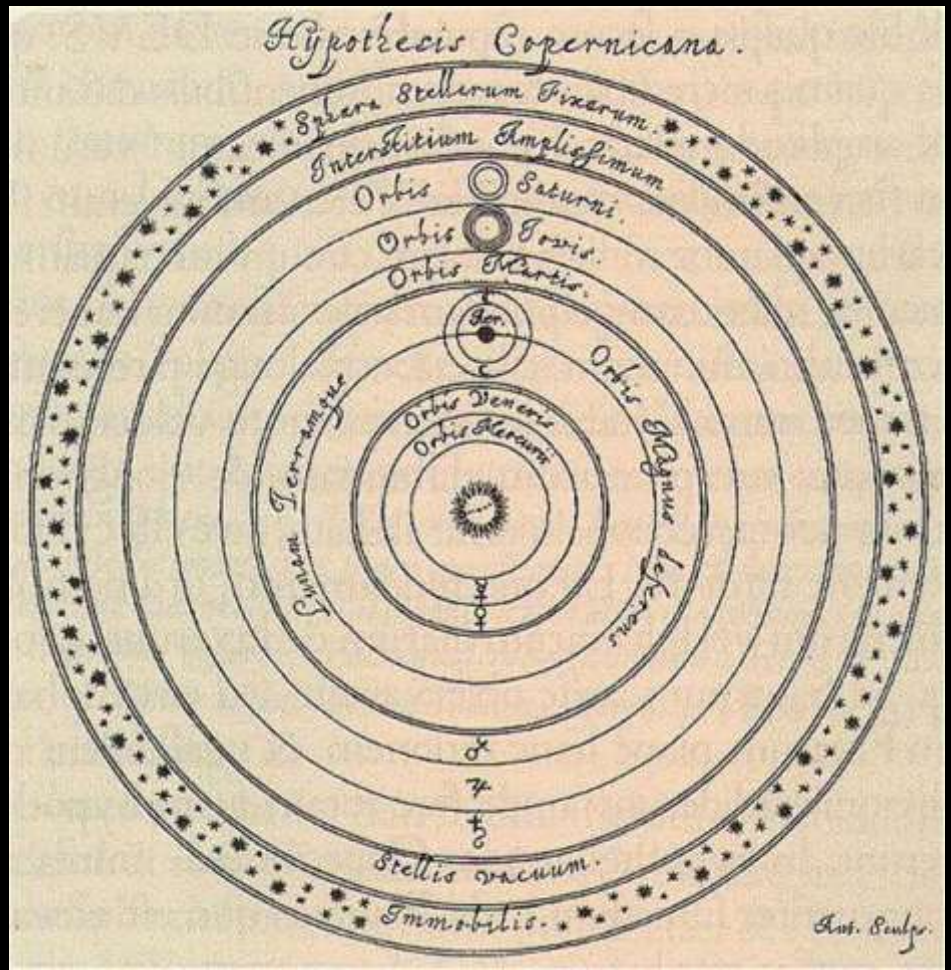


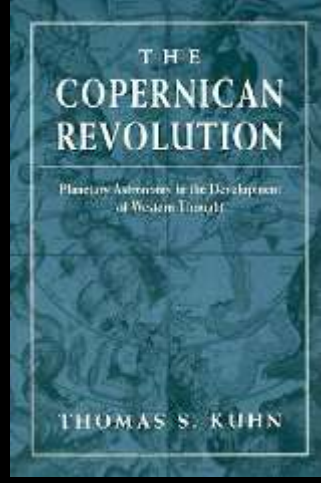


Fixing Ptolemy - The Scientific Revolution 1543-1687

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



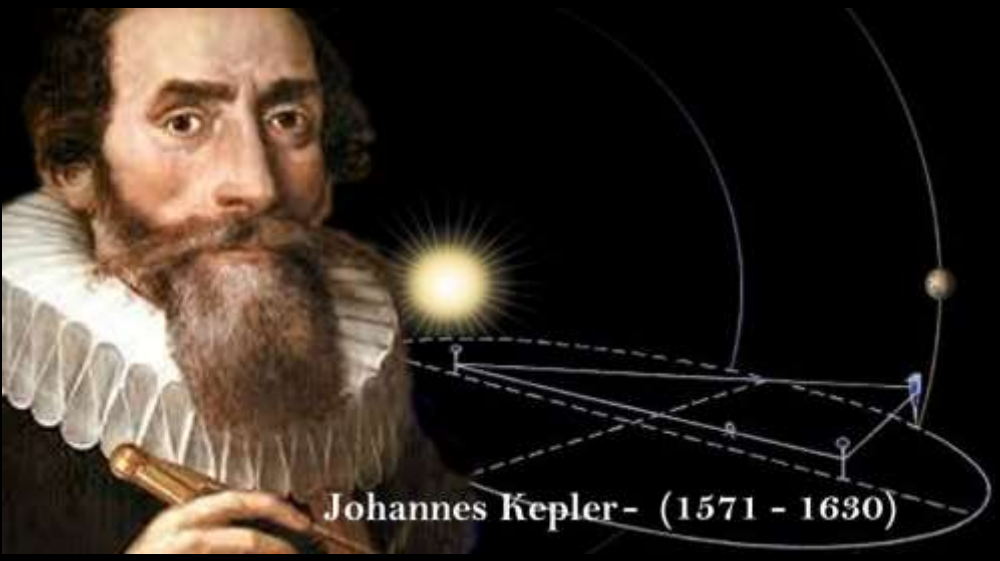




Fixing Copernicus
Johannes Kepler (1571–1630)

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



ASTRONOMIA NOVA
AITIOΛOΓHTOΣ,
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,

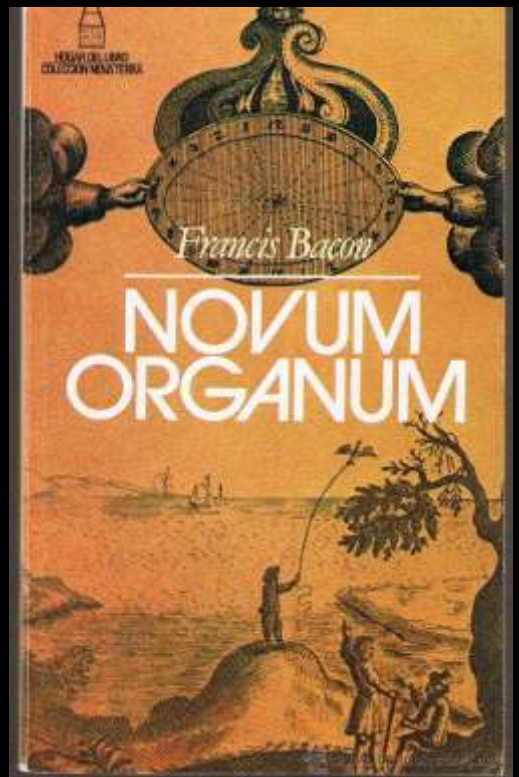
A Sᵉ. Cᵉ. Mᵗⁱᵉ Sᵉ. Mathematico
JOANNE KEPLERO,

Cum ejusdem Cᵉ. Mᵗⁱᵉ privilegio ſpeciali
Anno æræ Dionyſianæ clɔ Iɔ c ix.

Experimental Natural Philosophy “take the question to nature”

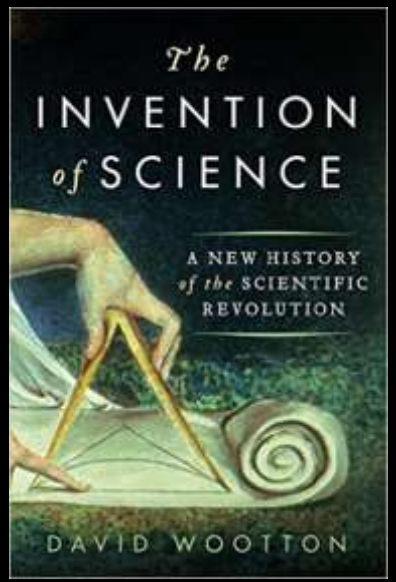
Francis Bacon 1561 – 1626

- an English philosopher, statesman, lawyer, and pioneer of the scientific method
- 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)



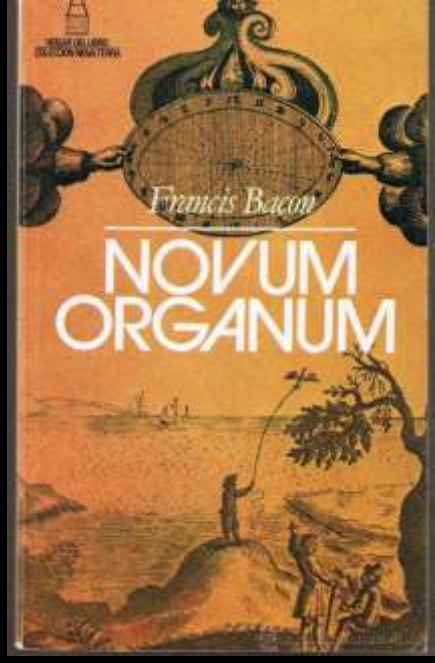
Bacon – Discovery, Scientific Travelers, and The Scientific Revolution 1543-1687

- 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."
- Were medieval and early modern natural philosophy continuous with each other or discontinuous?

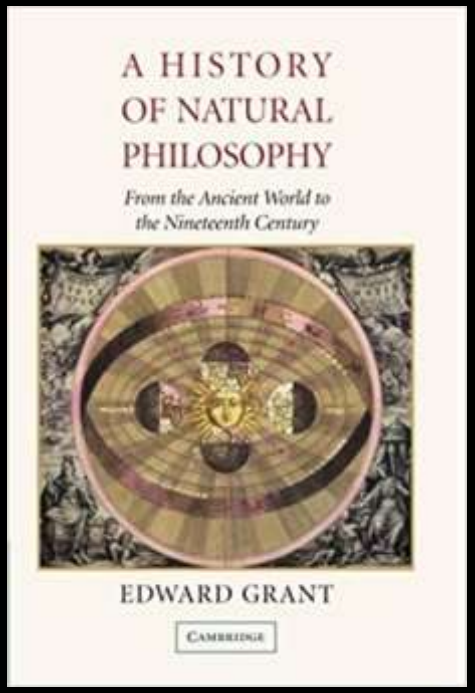


Bacon – Natural Philosophy, Mathematics, and the Exacts Sciences

- 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

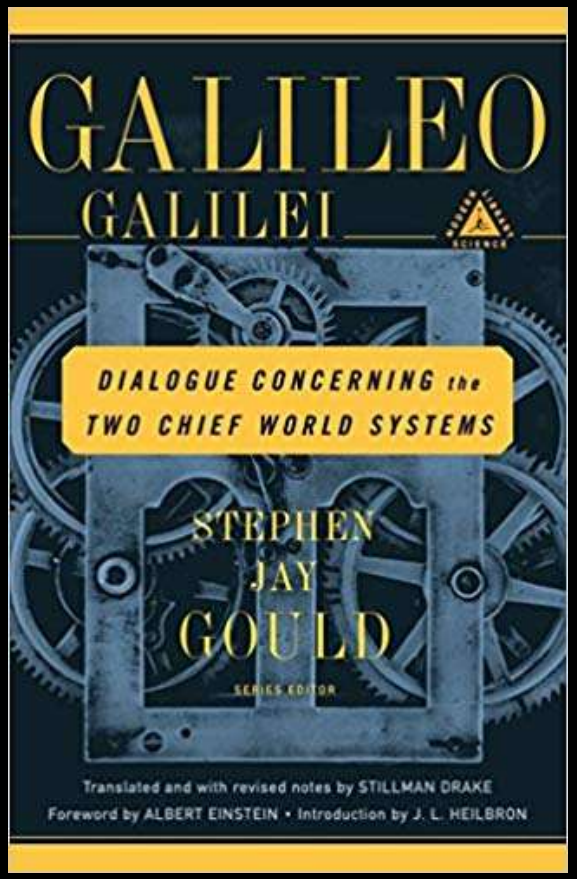


De-throning Aristotle – Galileo 1564-1642

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).

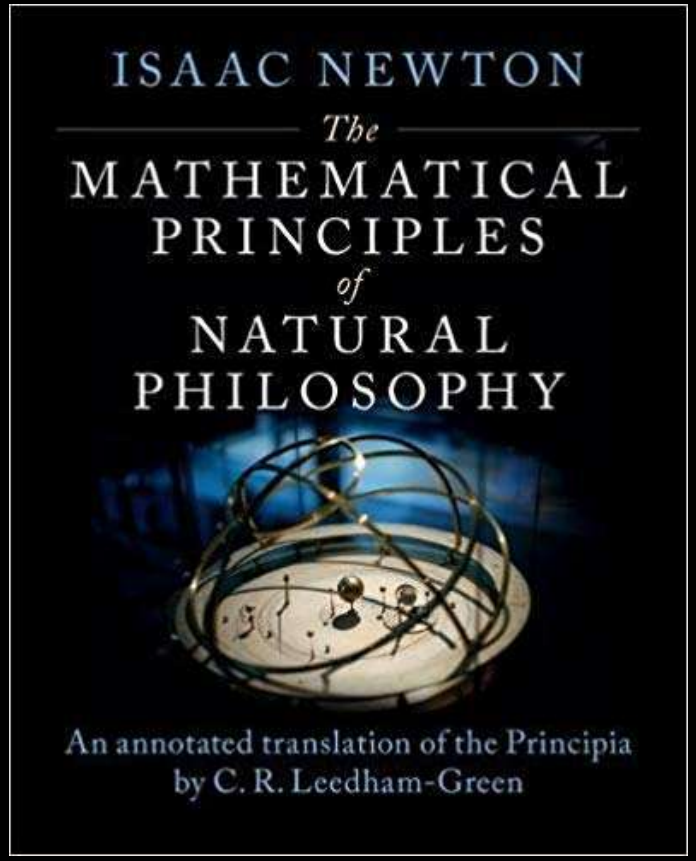
In their place he left only one element, corporeal matter, and a different way of describing the properties and motions of matter in terms of the mathematics



Reconciling Mathematics and Natural Philosophy

Isaac Newton (1642–1727)

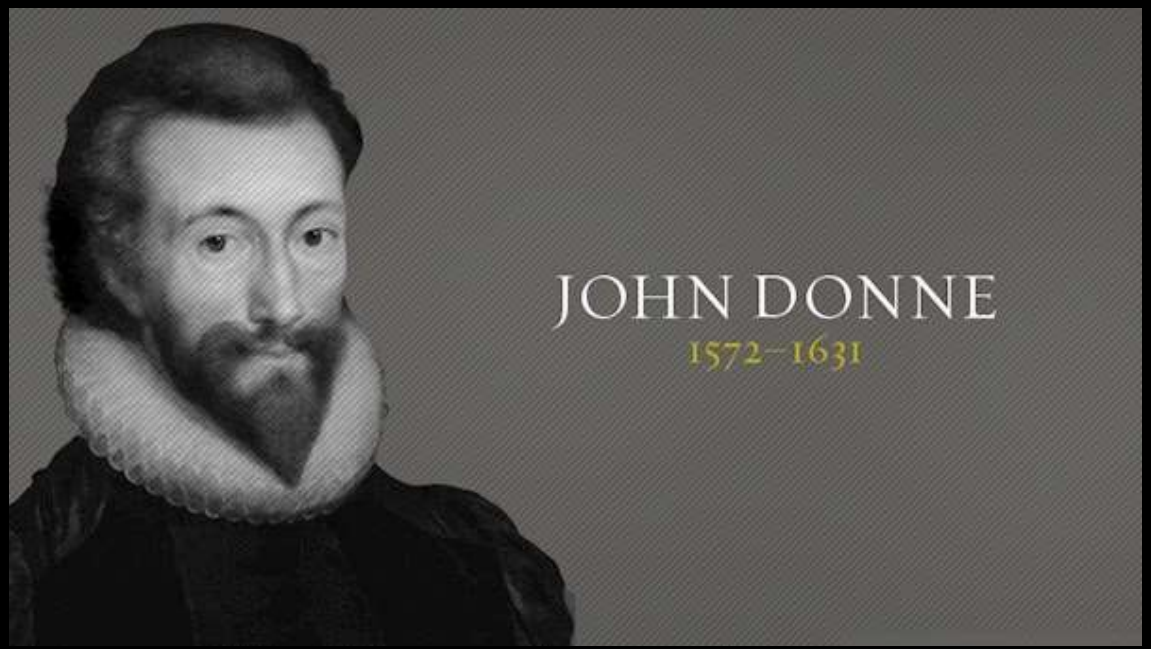
- *Philosophiae Naturalis Principia Mathematica* (1687), whose title translates to "Mathematical Principles of Natural Philosophy“
- Grant (2007) By the end of the 17th century, the transformation of natural philosophy was manifest in Newton’s great work “the very title of which reveals that a union 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.”
- “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…”

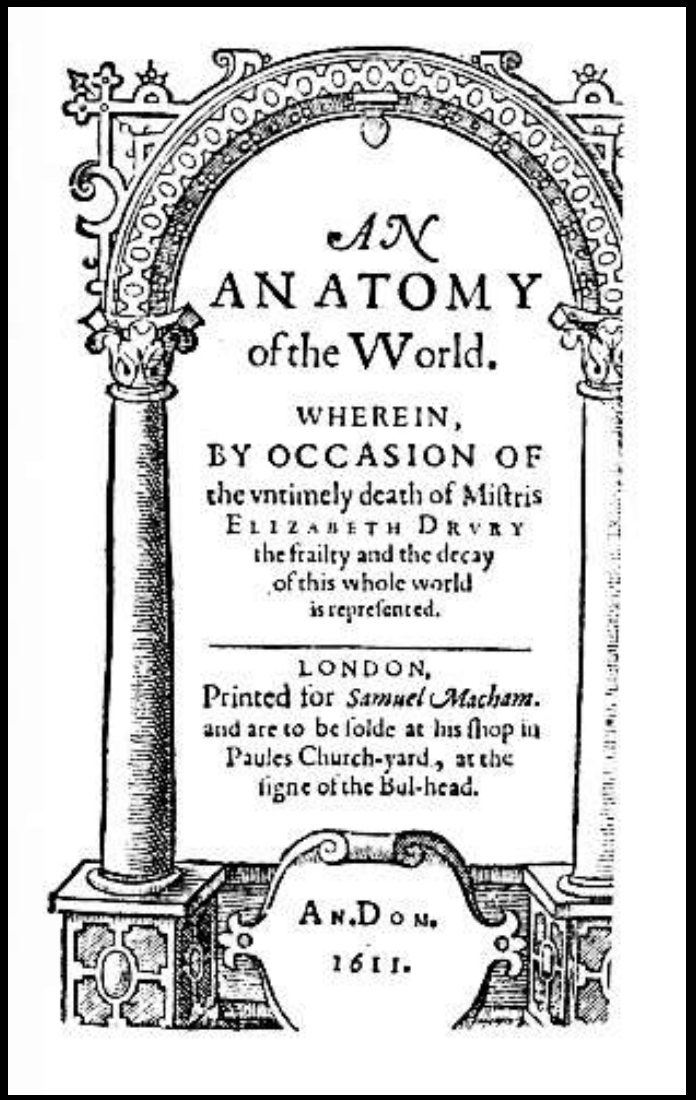


1687

An Anatomy of the World
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;

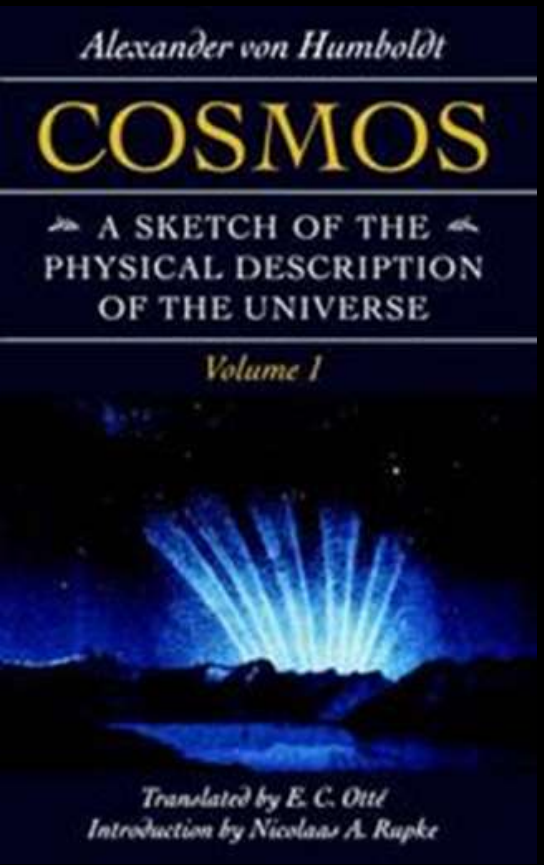


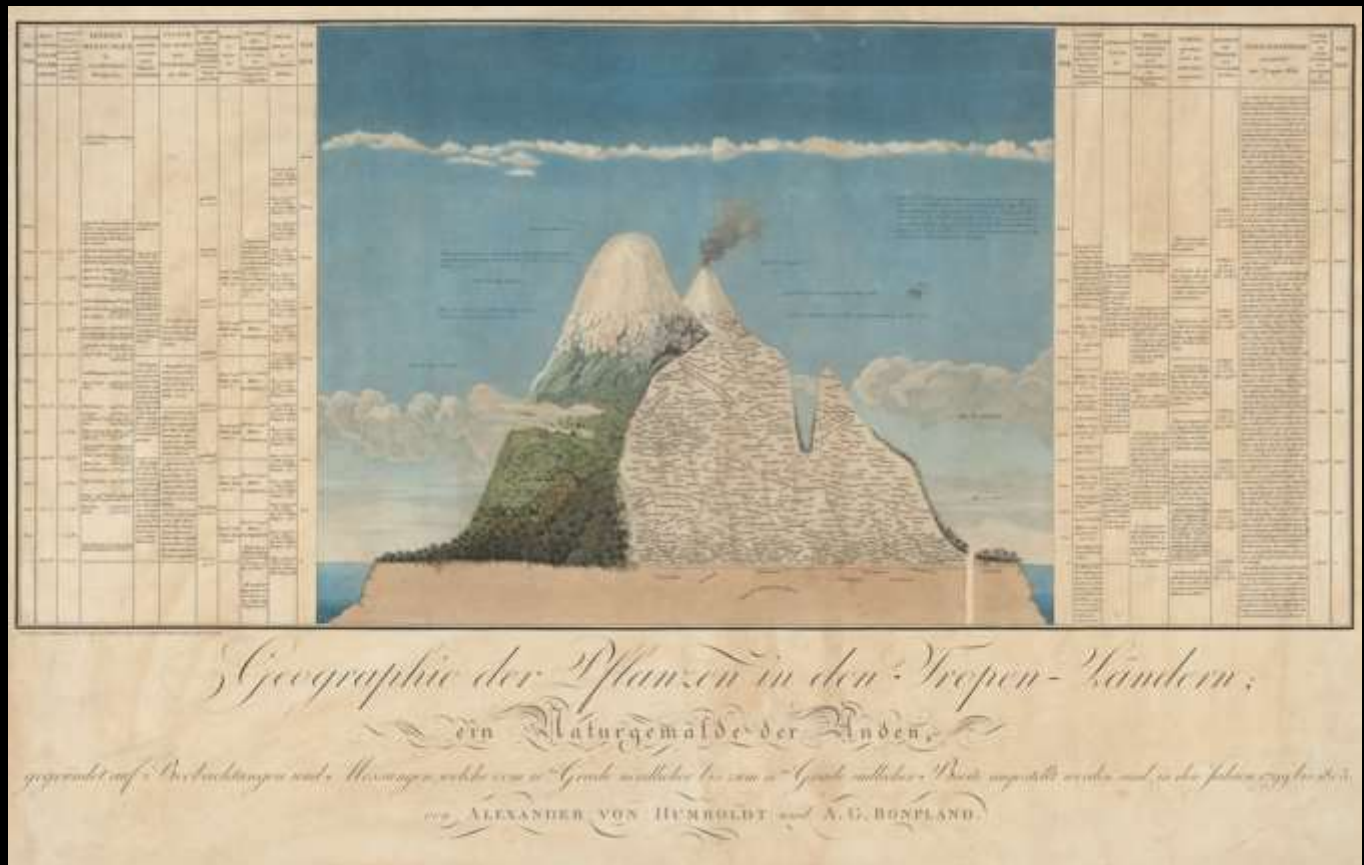

AN
ANATOMY
of the World.
WHEREIN,
BY OCCASION OF
the vntimely death of Miſtris
ELIZABETH DRVRY
the frailty and the decay
of this whole world
is repreſented.
LONDON,
Printed for *Samuel Macham.*
and are to be ſolde at his ſhop in
Paules Church-yard, at the
ſigne of the Bul-head.
AN. DOM.
1611.

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





Humboldtian Science

1. Explore – “Nature speaks and the scientist must go out and listen”
2. Collect – gather data for or against an idea/theory
3. Measure – widespread, accurate, collaborative
4. Connect – detect patterns that point to underlying laws
5. Cosmopolitan science – international collaboration

“the accurate measured study of widespread but interconnected real phenomena in order to find a definite law and a dynamic cause”