



## 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

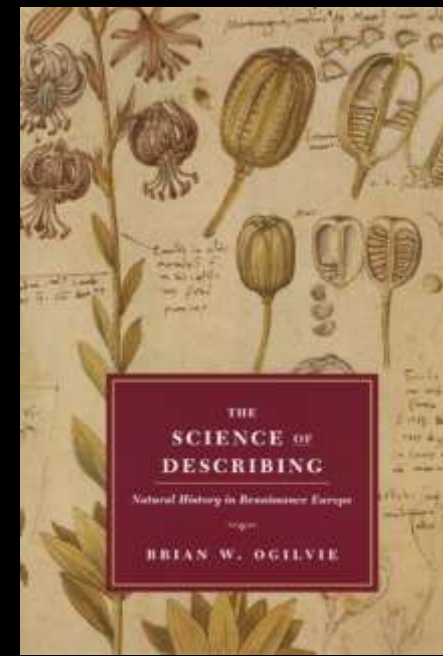
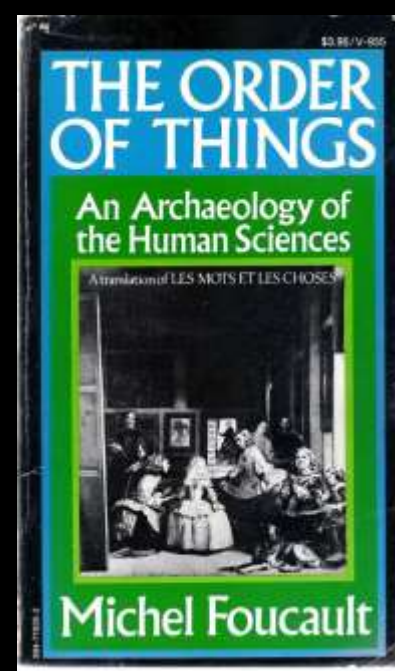
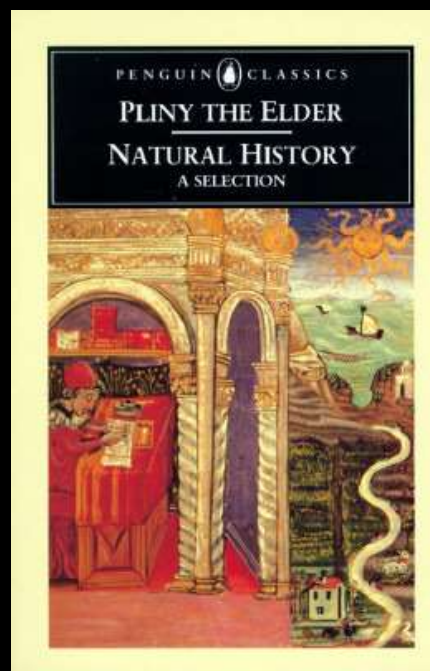
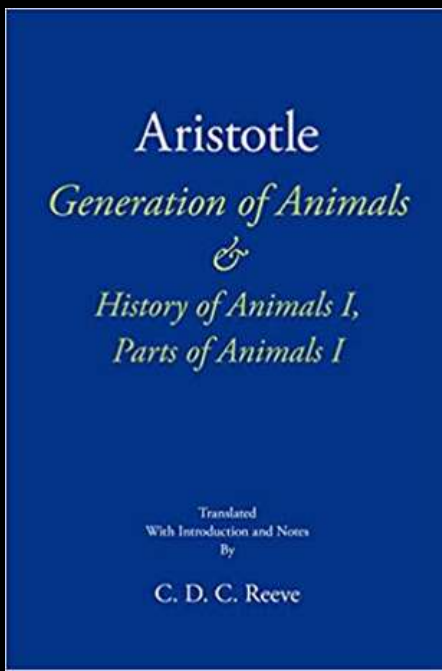




## Natural History and the Taxonomy of Nature

Kevin M. Anderson

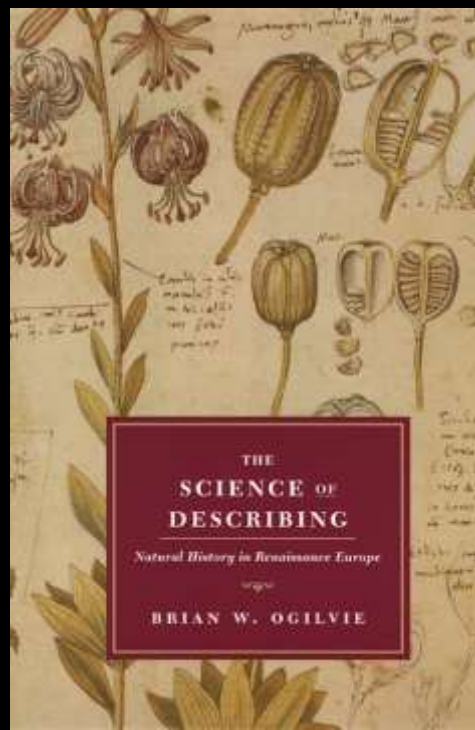
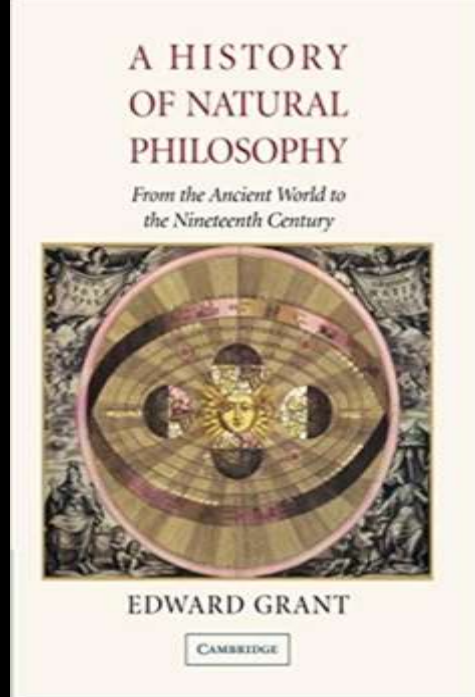
Austin Water Center for Environmental Research



# Natural History and Natural Philosophy

## Understanding Order and Change

- 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 - reasoning and explanations about nature
- Natural History - qualitative and descriptive study of nature
- *Naturalis Historia* - The word “historia” is closer to investigation or research rather than our word “history” but the books of their nature research were titled “Natural History”
- Ogilvie – Natural History “invented” in the Renaissance  
“Description, as a central problem, marks Renaissance natural history off from its medieval predecessors and its seventeenth-century successors.”
- Middle Ages → Renaissance Natural History → Scientific Revolution
- Natural History → Biology



# Natural History

Aristotle → Humboldt

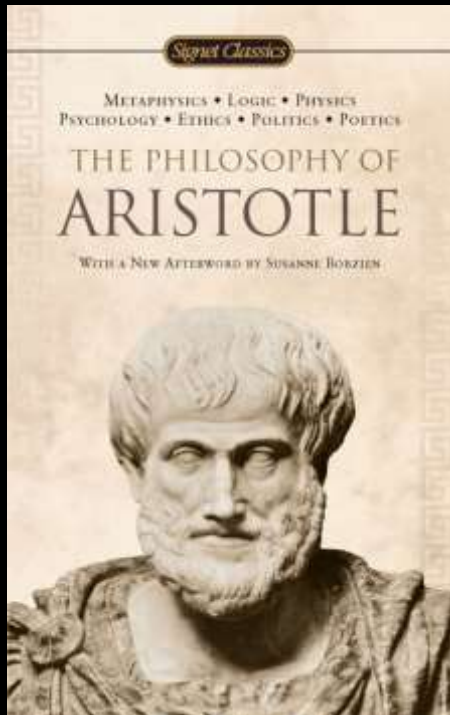
- Observation
- Description
- Encyclopedias
- Artists as Naturalists
- Collecting
- Classification
- Taxonomy



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.

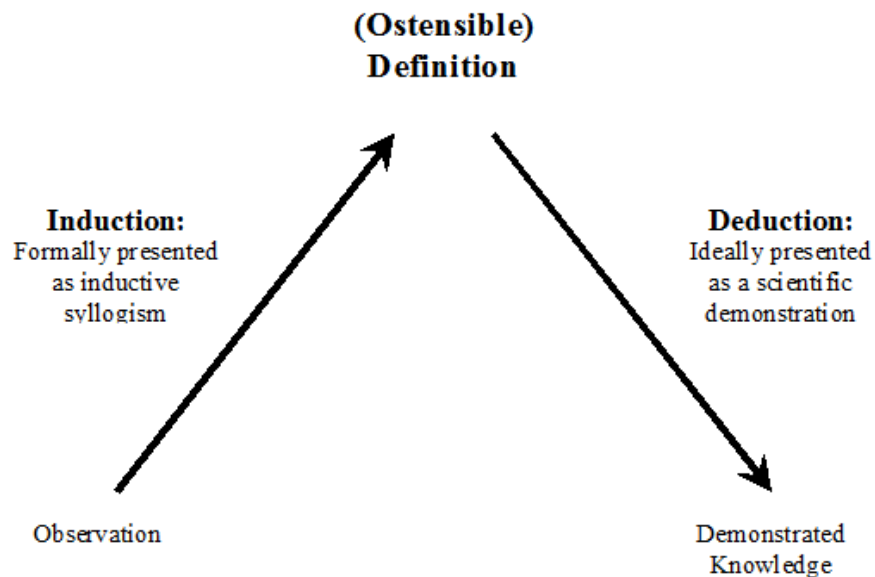
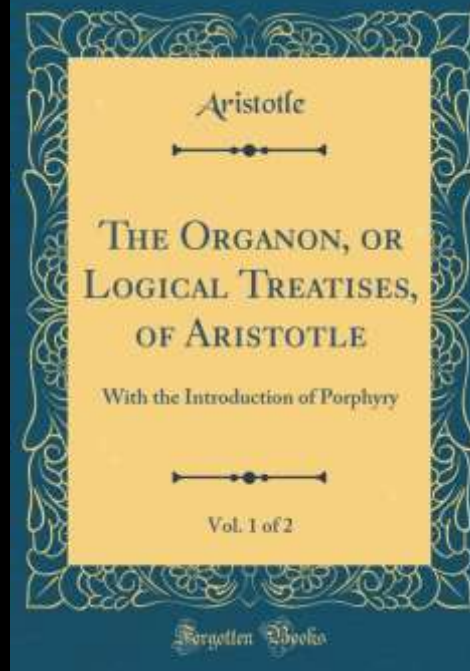
Plato gestures to the heavens, representing his belief in the Forms while holding the *Timaeus*.



# Aristotelian Logic – Knowledge of Nature

## The Many and the One

- Aristotle's logical treatises are called the *Organon* - Greek for "tool"
- Like his teacher Plato, Aristotle's philosophy aims at the universal.
- Plato believes that the universal exists apart from particular things, and is related to them as their independent prototype (and eternal exemplar) the Form.
- Aristotle, however, found the universal in particular things, which he called the essence of things,

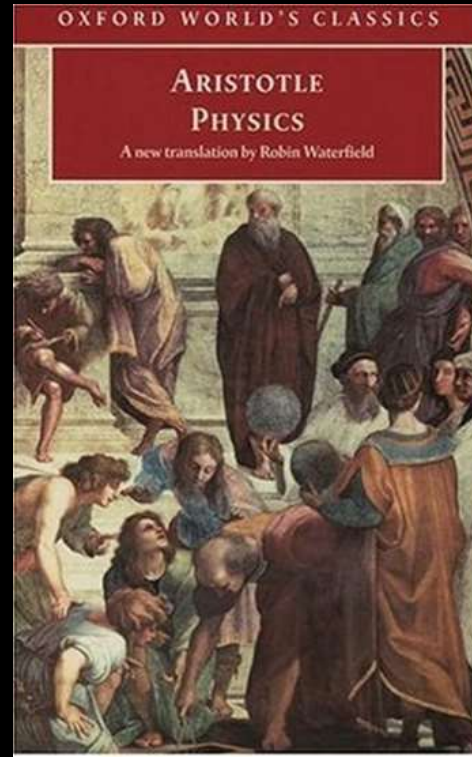


- For Aristotle, therefore, logic implies the ascent from the study of particular phenomena to the knowledge of essences (induction) producing a logic that tells us what belongs to what (kinds).
- Defining Essence - Spiders have eight legs.

# Aristotle's Terrestrial Cosmos

## The Mess of the Many – How to explain Order and Change?

- Things with separate existence (individual particulars)
- Things that are changeable
- Change - things come into being, grow, mature, decay, and die
- 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

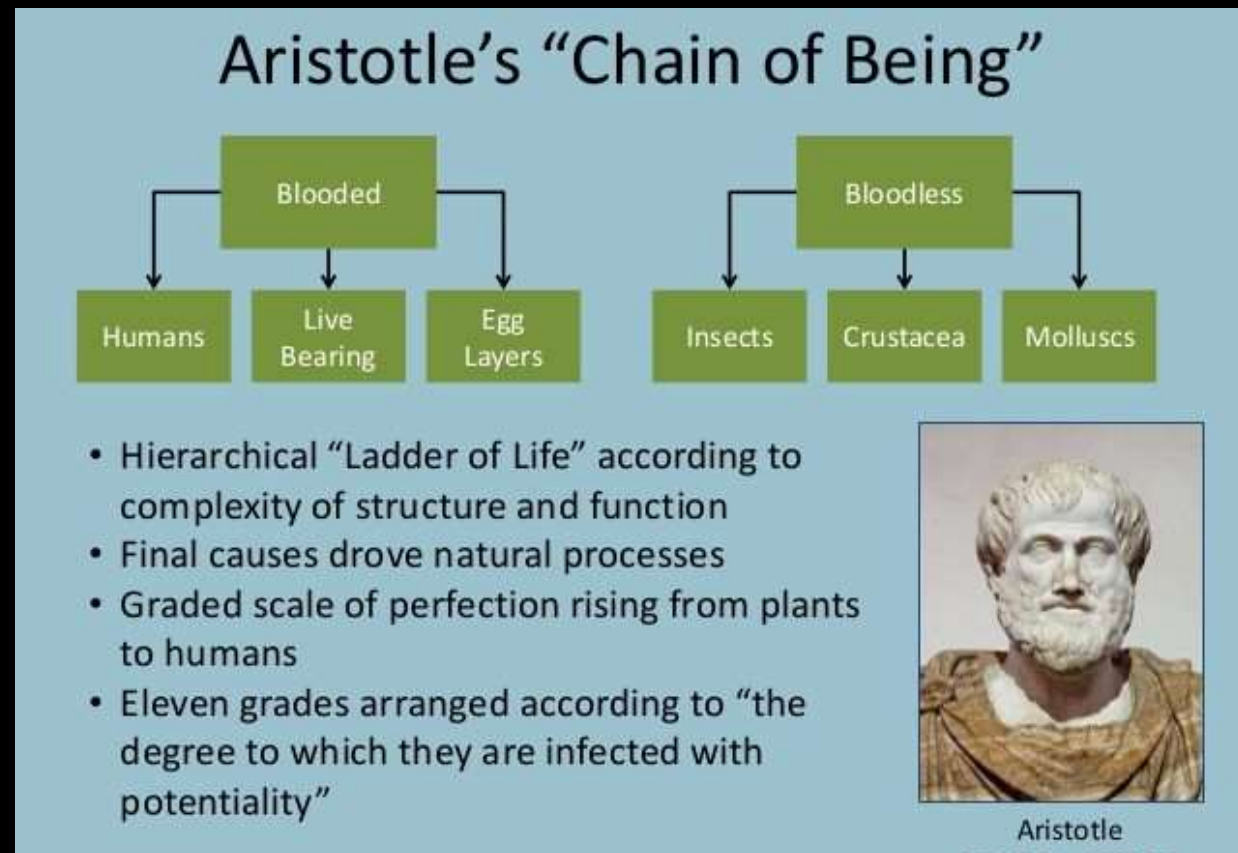
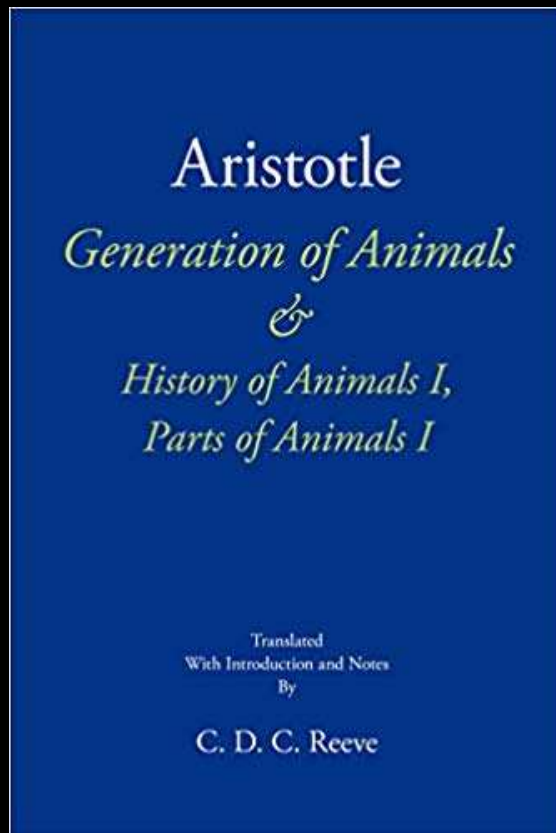


# The Order of Nature – “Scala Naturae”

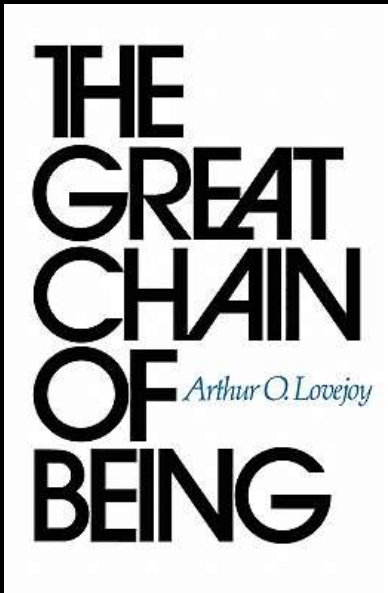
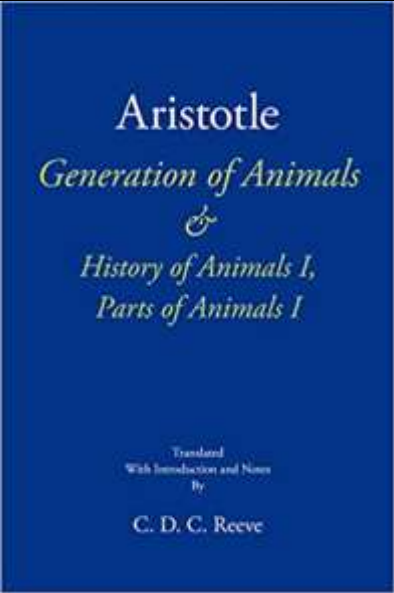
## The Classification of Living Things

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 “Ladder of Life” (scala naturae) or “Chain of Being” placing them according to complexity of structure and function so that higher organisms showed greater vitality and ability to move







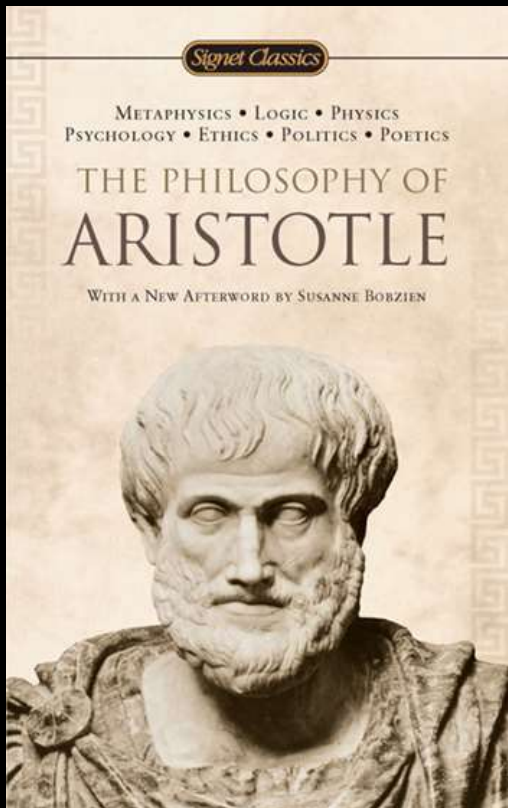
# The First Taxonomy

## The Classification of Living Things

Plants lacked sensation, motion, and reason, and so are ranked lowest on the scale.

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			

# Post-Aristotle Greek Natural History

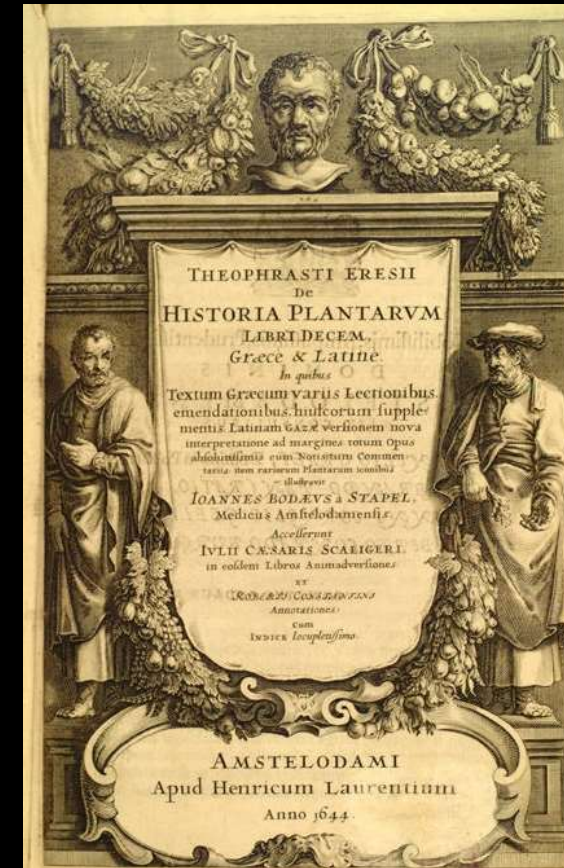
Theophrastus 371 – 287 BC

## The Father of Botany and Plant Taxonomy

Studied in Plato's school and after Plato's death, he was Aristotle's student. Aristotle bequeathed to Theophrastus his writings and designated him as his successor at the Lyceum.

The most important of his books are two large botanical treatises, *Enquiry into Plants*, and *On the Causes of Plants*, which constitute the most important contribution to botanical science during antiquity and the Middle Ages, the first systemization of the botanical world.

*On the Causes of Plants* was originally eight books, of which six survive. It concerns the growth of plants; the influences on their fecundity; the proper times they should be sown and reaped; the methods of preparing the soil, manuring it, and the use of tools; and of the smells, tastes, and properties of many types of plants.



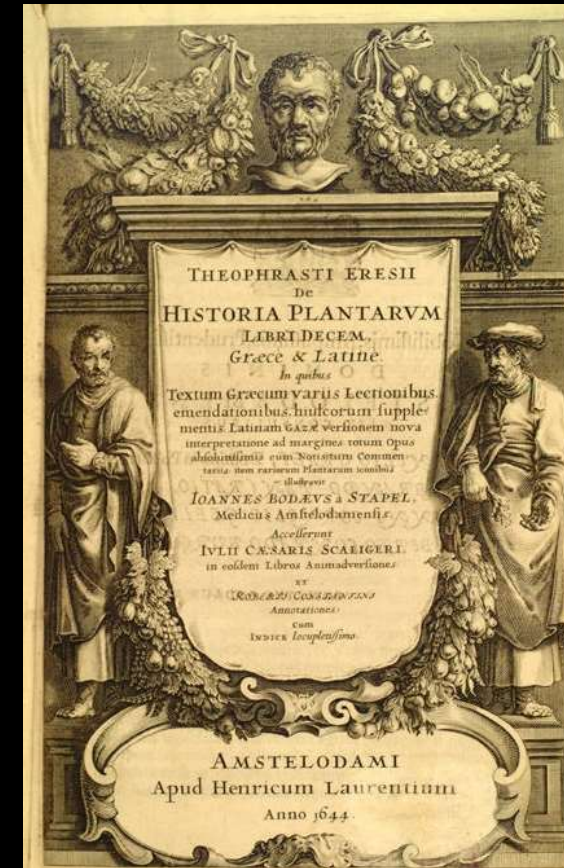
# Post-Aristotle Greek Natural History

Theophrastus 371 – 287 BC

## The Father of Botany and Plant Taxonomy

The *Enquiry into Plants* was originally ten books, of which nine survive. The work is arranged into a system whereby plants are classified according to their modes of generation, their localities, their sizes, and according to their practical uses such as foods, juices, herbs, etc.

Another of his innovations was to classify plants using a hierarchical arrangement with an attention to defining characteristics based on morphology [external and internal form – trees, shrubs, under-shrubs, herbs], as well as understanding their life history, mode of reproduction and response to environmental factors earned him the title of “father of plant taxonomy.”

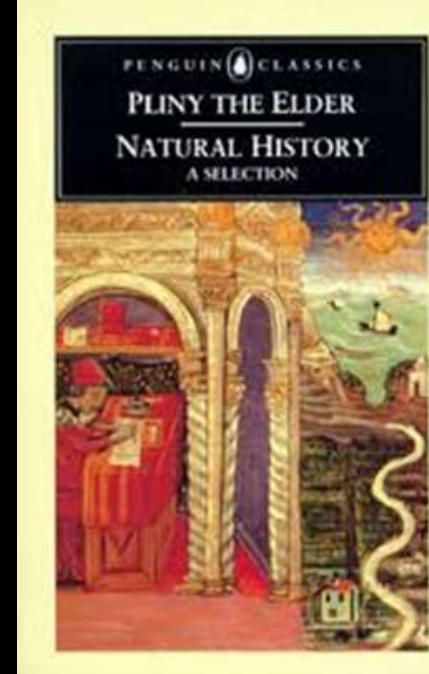


# Roman Natural History - The Encyclopedia of Life

Pliny the Elder (23 – 79 AD)

*Naturalis Historia*

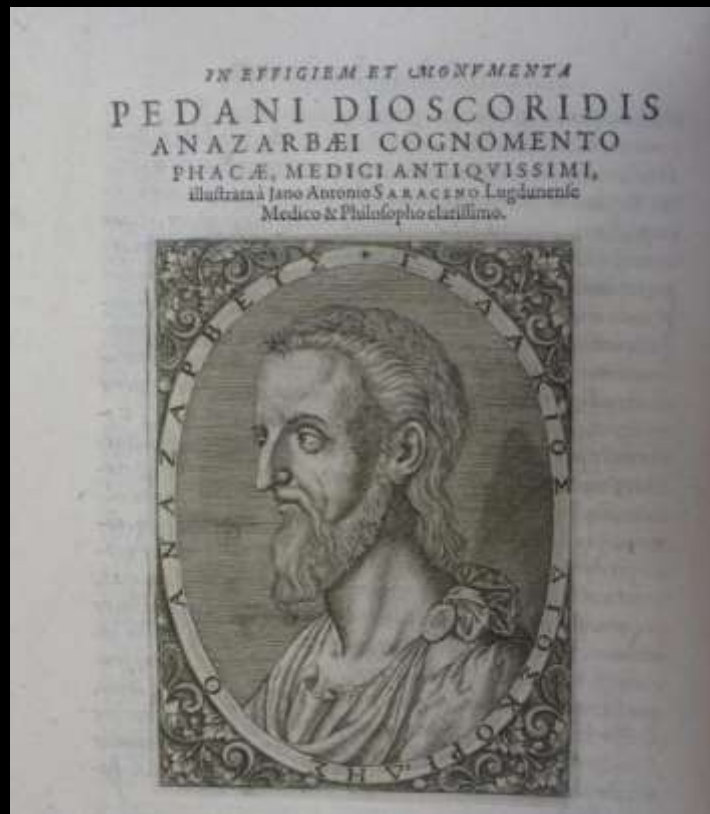
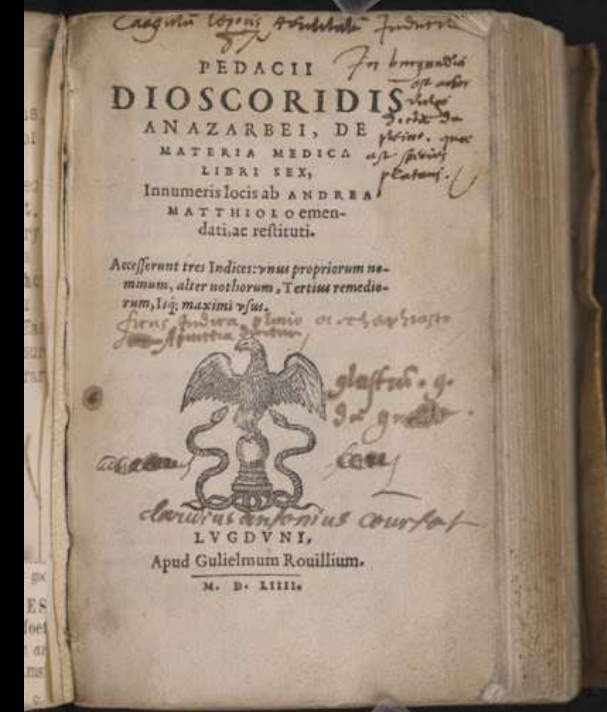
- A military officer and lawyer
- Spending most of his spare time studying, writing or investigating natural and geographic phenomena in the field, he wrote an encyclopedic work, *Naturalis Historia*, which became a model for all natural histories and encyclopedias, in terms of the breadth of subject matter examined, the need to reference original authors, and a comprehensive index list of the contents.
- The *Naturalis Historia* is one of the largest single works to have survived from the Roman empire and purports to cover the entire field of ancient knowledge, based on the best authorities available to Pliny.
- Both the actual and the mythical/fantastical
- It encompasses the fields of botany, zoology, astronomy, geology and mineralogy as well as the exploitation of those resources.
- “My subject is a barren one – the world of nature, or in other words life; and that subject in its least elevated department, and employing either rustic terms or foreign, nay barbarian words that actually have to be introduced with an apology.”



# Roman Medicine and Plants – the Pharmacopeia

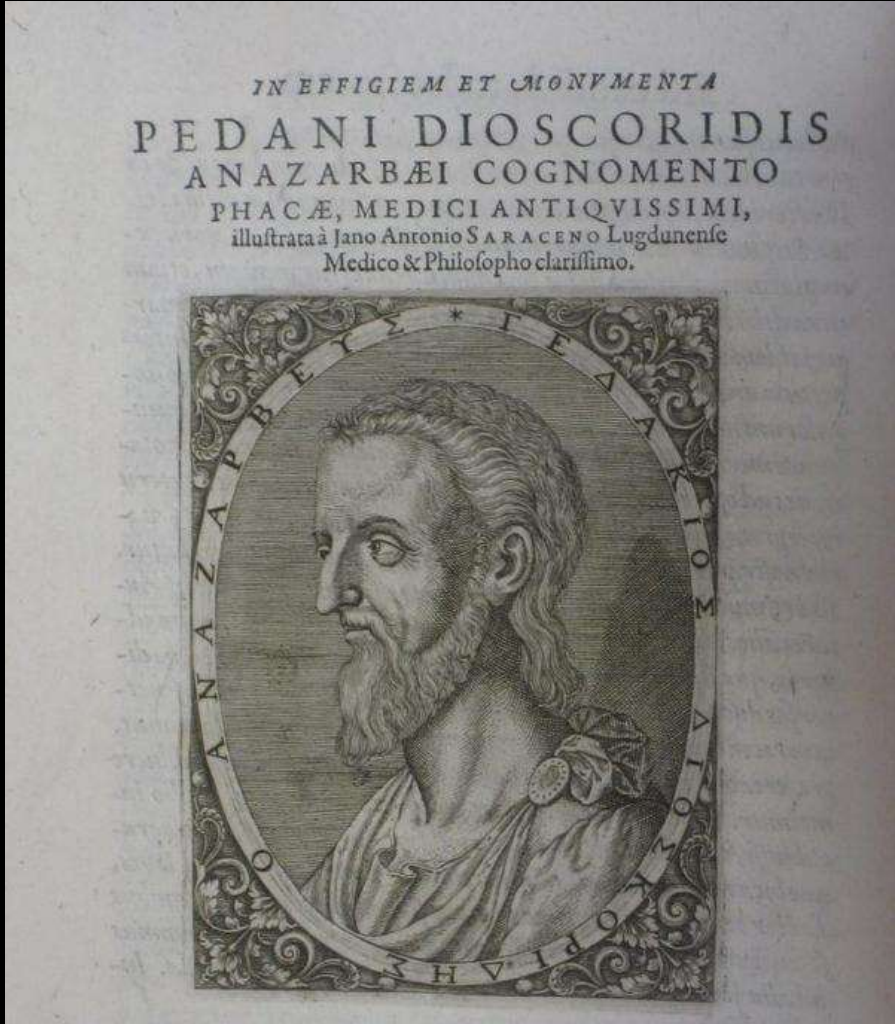
## Pedanius Dioscorides (c. 40 – 90 AD)

- a Greek physician employed in the Roman army, pharmacologist, botanist
- author of *De Materia Medica* (*On Medical Material*)
- 5-volume Greek encyclopedia about herbal medicine and related medicinal substances (a pharmacopeia), that was widely read for more than 1,500 years.



# De Materia Medica

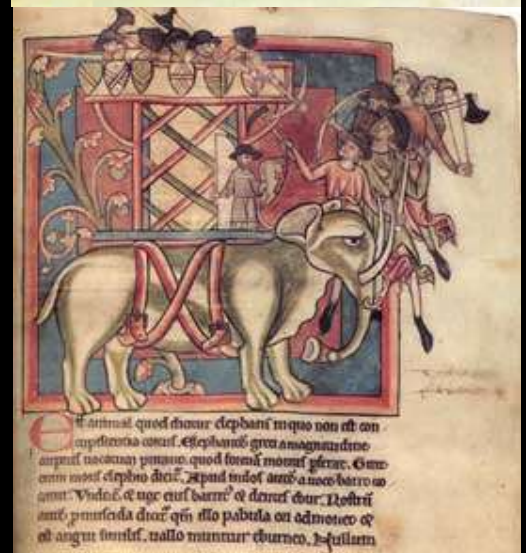
- Written in five books around 77AD, this work deals with approximately 1,000 simple drugs.
- Descriptions of nearly 600 plants, including cannabis, water hemlock, and peppermint
- Both the actual and the mythical/fantastical
- Mandrake – aphrodisiac and legend that it screams when pulled from the ground





# Medieval Natural History - Bestiaries

- Both the actual and the mythical/fantastical
- Medieval bestiaries contained detailed descriptions and illustrations of species native to Western Europe, exotic animals and what in modern times are considered to be imaginary animals.
- Descriptions of the animals included the physical characteristics associated with the creature, although these were often physiologically incorrect, along with the Christian morals that the animal represented.





## “Natural History was invented in the Renaissance...”

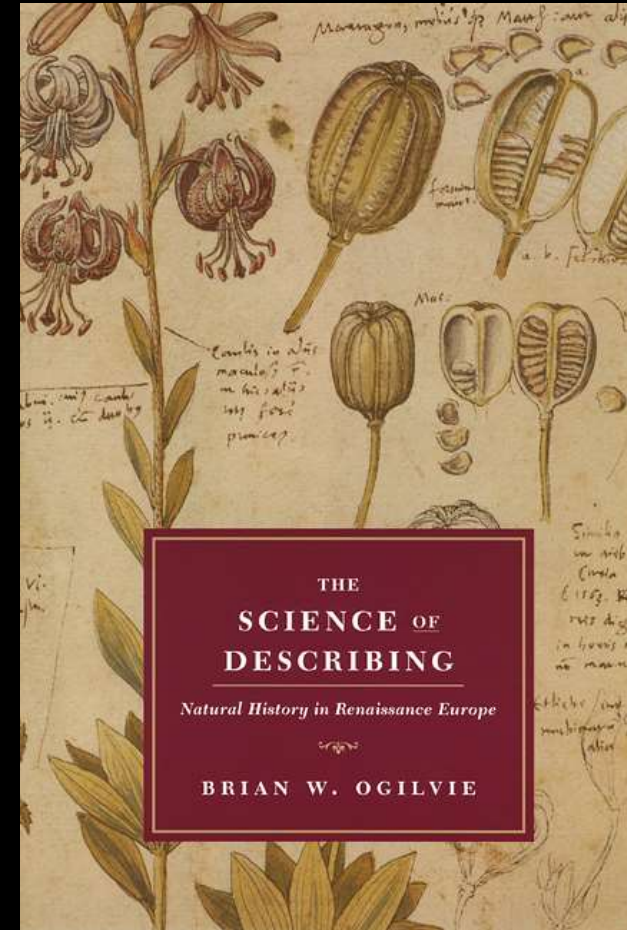
“Renaissance naturalists were unabashedly concerned with particulars and their description...”

Description was a way to grasp the multiplex beauty and diversity of the natural world”

Middle Ages (1000-1300) – Herbals, Medicine

Renaissance (1300 – 1600) – Description, Artists as Naturalists

- Description leads away from the fantastical towards the real
- Realism and realistic depictions
- A community of naturalists
- “Only in the middle of the sixteenth century did naturalists come to think of themselves as practitioners of a discipline that, though related to medicine and natural philosophy, was distinct from both...No single individual invented natural history; by its very nature, it could be the product only of a community.”



# Renaissance 14<sup>th</sup> – 16<sup>th</sup> Centuries

Konrad Gessner (1516-1565)

His five-volume *Historiae animalium* (1551–1558)

The first zoological work that attempts to describe all the animals known, and the first bibliography of natural history writings. He showed the animals' places in history, literature and art.

Fantastical creatures and newly discovered creatures not in Aristotle



# Albrecht Dürer (1471–1528)

## Description and Realism



Albrecht Dürer

Realism and realistic depictions



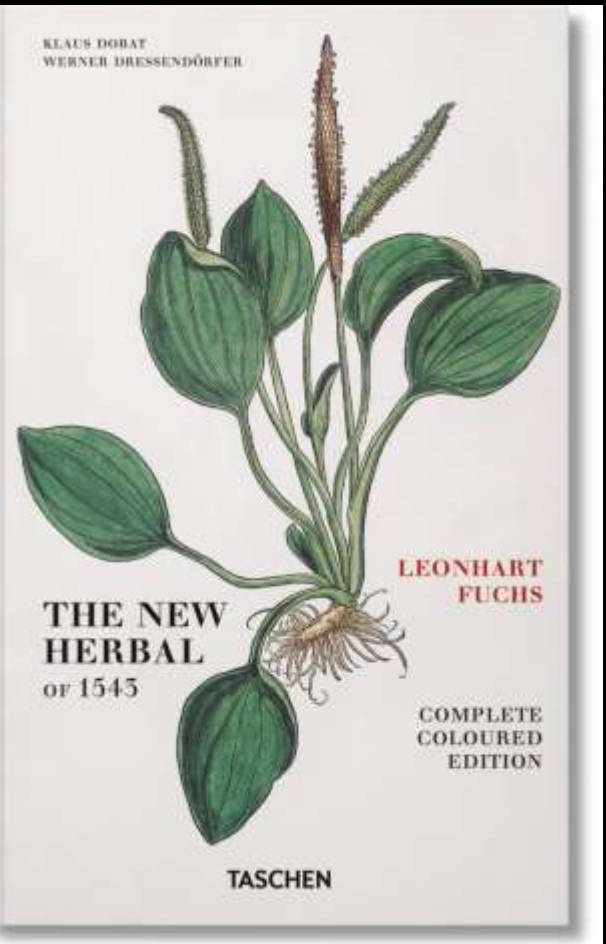
1502

AD

# Leonhart Fuchs (1501 – 1566)

*De historia stirpium commentarii insignes*  
"Notable commentaries on the history of plants"  
(Basel, 1542) "New Kreüterbuch" in German (1543),  
"New Herbal" in English

Accurate and detailed woodcuts of plants

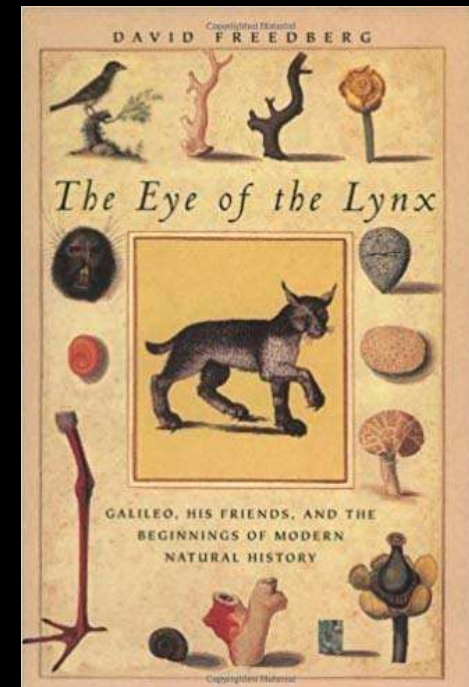


# From Renaissance to Scientific Revolution

## A Community of Naturalists

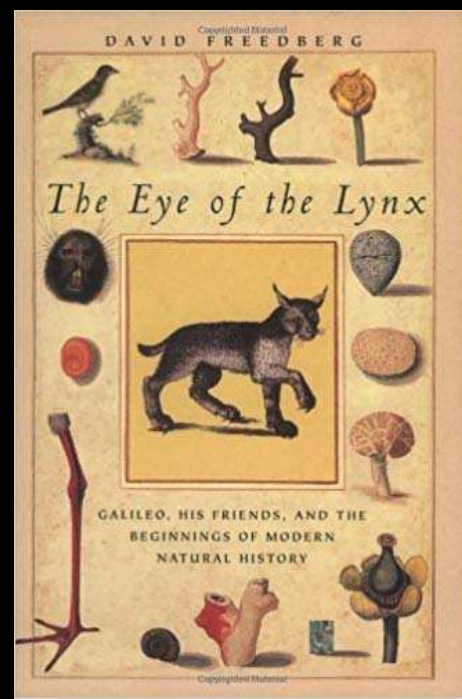
### The Academy of Linceans 1603-1630

- named after the sharp-eyed lynx and Lyncaeus, "the keen-sighted pilot of the Argonauts".
- Founded in 1603 by the 18-year-old Prince Federico Cesi, the Linceans were the first scientific academy.
- Aimed at the understanding of all natural sciences through a method of research based upon observation, experiment, and the inductive method. Their goal was to penetrate the secrets of nature, observing it at both microscopic and macroscopic levels
- Galileo became a member of Cesi's academy in 1611. As Galileo made discoveries in the heavens, the Linceans turned their gaze to earth.
- Initially Cesi and the Linceans toured the hilly countryside around the family's small castle in southern Umbria, gathering specimens that were then drawn by professional draftsmen; later they also included specimens from China and the Americas.
- They would continue this work for 27 years.



# Beyond Descriptive Natural History “Establishing Relationships”

- Linceans had made a "deep investment in the worth of appearance" by creating their extraordinary visual archive of nature. They included 2,000 studies of fungi, plants, mosses and lichens, and among them were the "earliest surviving drawings ever made with the aid of a microscope". The magnified drawings of fungi, "observed with extraordinary closeness and intensity", represent the beginning of modern mycology.
- “It dawned on Cesi that the drawings, with their exquisite attention to detail, texture, color and the unique particularity of each specimen, were preventing the Linceans from grasping the underlying order of things.” (Freedberg)
- “Progress in natural history, as in other sciences, would come through establishing relationships, not by collecting archives of illustrations.” (Freedberg)



# Magnification and Underlying Order

## The Microscopic New World

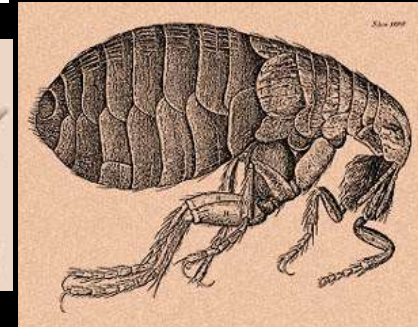
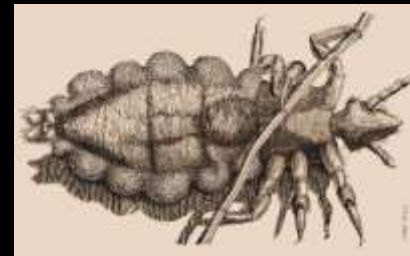
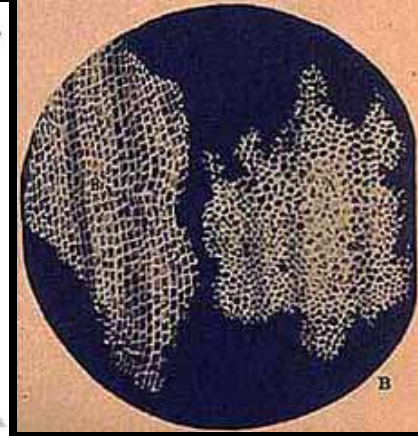
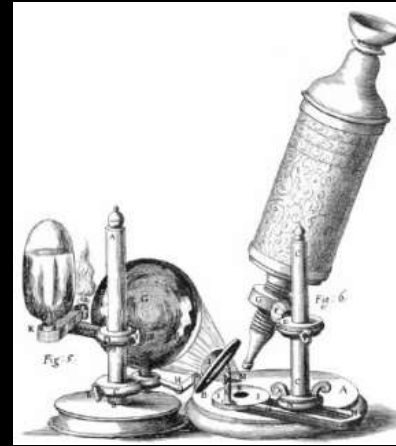
Robert Hooke (1635-1703)

Hooke's reputation in the history of biology largely rests on his book *Micrographia*, published in 1665. Hooke devised the compound microscope and illumination system and used it in his demonstrations at the Royal Society's meetings.

Perhaps his most famous observation was his study of thin slices of cork, depicted above right. In "Observation XVIII" of the *Micrographia*, he wrote:

*"I could exceedingly plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the pores of it were not regular. . . . these pores, or cells, . . . were indeed the first microscopical pores I ever saw, and perhaps, that were ever seen, for I had not met with any Writer or Person, that had made any mention of them before this"*

Hooke had discovered plant cells -- more precisely, what Hooke saw were the cell walls in cork tissue. He coined the term "cells": the boxlike cells of cork reminded him of the cells of a monastery.



MICROGRAPHIA RESTAURATA:  
OR, THE  
COPPER-PLATES

OF  
Dr. HOOKE'S Wonderful Discoveries  
BY THE  
MICROSCOPE,

Reprinted and fully Explained:

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Are brought together in a narrow Compaſs

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*Revisum Notisæ vulgares anglicæ in Minimis hinc est.*  
PLAN. Hist. Nat. Lib. XI. C. 2.



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# Magnification and New Worlds

## The Natural History of the Microcosmos

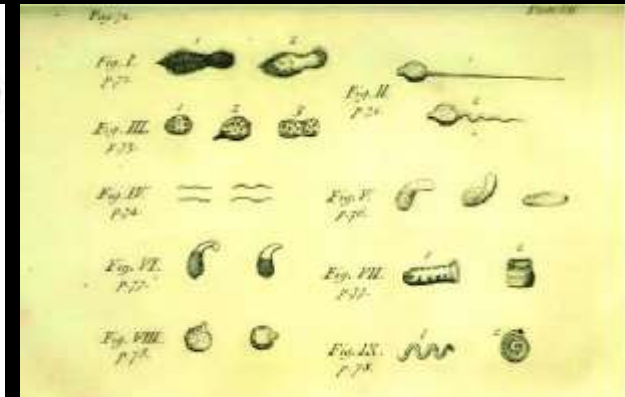
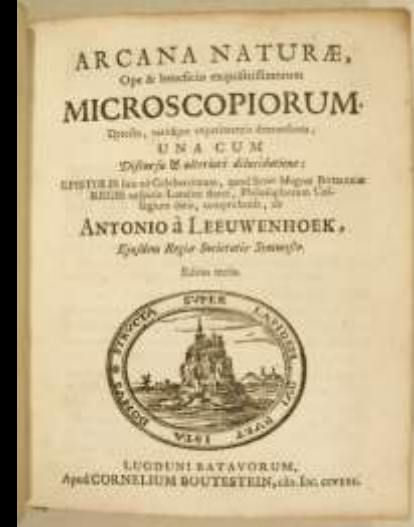
Antony van Leeuwenhoek (1632 – 1723)

The first to see bacteria

Until the day Leeuwenhoek put a glass phial of lake water in front of his microscope lens, no one had any idea of the extent of the world's microbial populations.

*“Looking at this water...the motion of most of these animalcules was so swift, and so various – upwards, downwards, and round about, that twas wonderful to see.”*

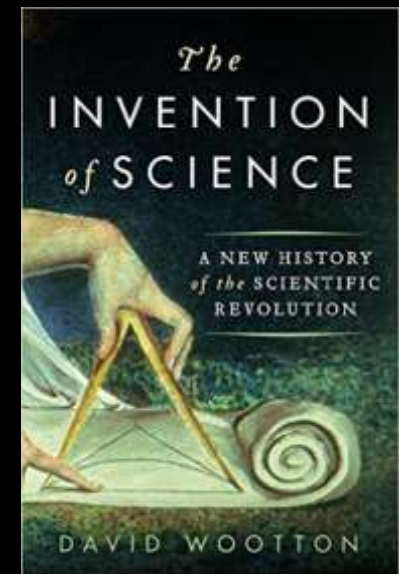
The Utrecht museum has one of Leeuwenhoek's microscopes in its collection. This incredible instrument has a magnification factor of about 275x (even considering a scratch on the lens) with a resolution approaching one micron.



## Bacon – Discovery, Scientific Travelers Francis Bacon 1561 – 1626

### 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.”



# Classification and Taxonomy

John Ray (1627 – 1705)

His classification of plants in his *Historia Plantarum*, was an important step towards modern taxonomy.

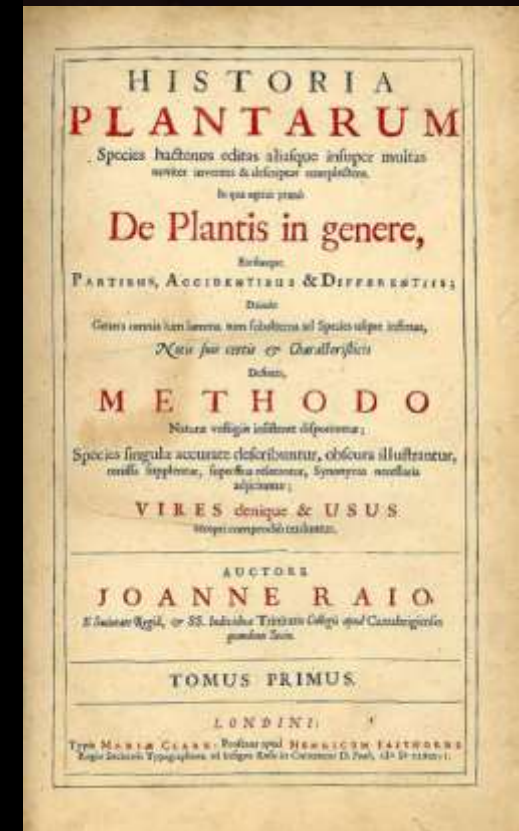
Ray rejected the system of dichotomous division by which species were classified according to an Aristotelean pre-conceived, either/or type system, and instead classified plants according to similarities and differences that emerged from observation.

Ray's system began with the division between -

- The imperfect or lower plants (Cryptogams)
- The perfect (planta perfecta) higher plants (Seed plants)

He divided the Seed Plants by morphology, e.g. trees (arbores), shrubs (frutices), subshrubs (suffrutices) and herbaceous plants (herbae) and lastly grouping them by common characteristics.

Ray's plant classification system was the first to divide flowering plants into monocots and dicots.



# Classification - Total morphology to classify organisms

Ray classified plants by overall morphology: the classification in his 1682 book *Methodus Plantarum Nova* draws on flowers, seeds, fruits, and roots.

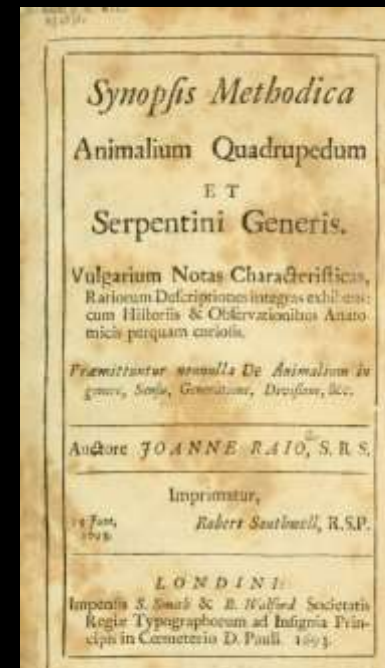
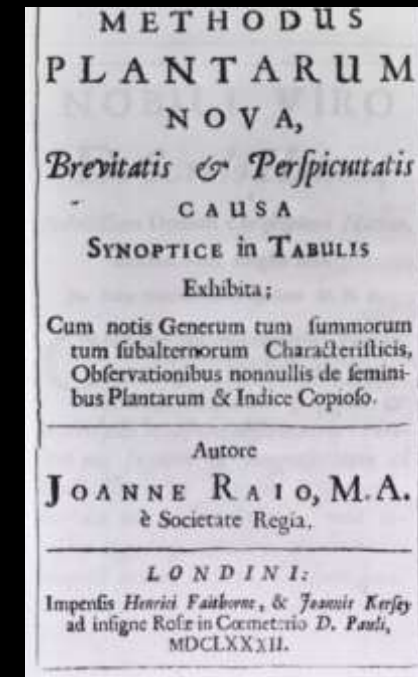
Instead of a single feature, he attempted to base his systems of classification on all the structural characteristics, including internal anatomy. By insisting on the importance of lungs and cardiac structure, he effectively established the class of mammals, and he divided insects according to the presence or absence of metamorphoses.

This method produced more "natural" results than "artificial" systems based on one feature alone; it expressed the similarities between species more fully.

He was the first to give a biological definition of the term species -

"... no surer criterion for determining species has occurred to me than the distinguishing features that perpetuate themselves in propagation from seed. Thus, no matter what variations occur in the individuals or the species, if they spring from the seed of one and the same plant, they are accidental variations and not such as to distinguish a species... Animals likewise that differ specifically preserve their distinct species permanently; one species never springs from the seed of another nor vice versa".

How do new species come into being? God



# Natural Theology and the Argument from Design

John Ray (1627 – 1705)

The Argument from Design asserts that the perceived evidence of deliberate design in the natural world demonstrates the necessity of an intelligent creator.

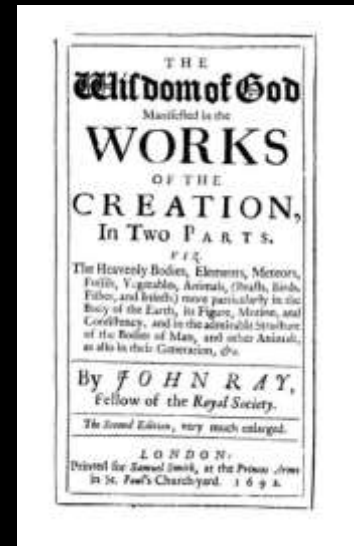
Ray believed that empirical study of Nature revealed divine order and design in the world and that the wisdom and power of God could be understood by studying His creation, the natural world.

*“There is for a free man no occupation more worthy and delightful than to contemplate the beauteous works of nature and honour the infinite wisdom and goodness of God.”*

Ray elaborated on his “natural theology” in *The Wisdom of God Manifested in the Works of the Creation* (1691), which was his most popular and influential book. It argued that the correlation of form and function in organic nature demonstrates the necessity of an omniscient creator.

However, Ray still supported scientific empiricism against the deductive rationalism of the scholastics, and he cautioned against blind acceptance of authorities:

*“Let us not suffice to be book-learned, to read what others have written and to take upon trust more falsehood than truth, but let us ourselves examine things as we have opportunity and converse with Nature as well as with books.”*



"Is it animal, vegetable or mineral?"

Carl Linnaeus 1707 – 1778

Swedish botanist, physician, and zoologist, who laid the foundations for the modern scheme of binomial nomenclature (*Genus species*).

The first edition of *Systema Naturae* was printed in 1735. He then returned to Sweden, where he became professor of botany at Uppsala.

This folio volume of only 11 pages presented a hierarchical taxonomy of the three kingdoms of nature: minerals, plants, and animals.

Each kingdom was subdivided into classes, orders, genera, species, and varieties. This hierarchy of taxonomic ranks replaced traditional systems of biological classification that were based on mutually exclusive divisions, or dichotomies.

Linnaeus could only base his scheme on the structural similarities of the different organisms.

He chose a different organ as the basis for four of six animal classes –  
Mammals - teeth

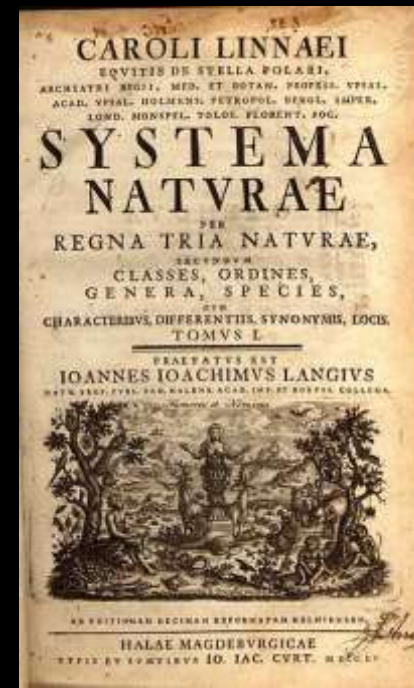
Birds - bills

Fish - fins

Insects - wings

Amphibians - limb structures and the way they breathed (gills or lungs)

Worms (his term for animals without a backbone that didn't fit elsewhere) - external characteristics



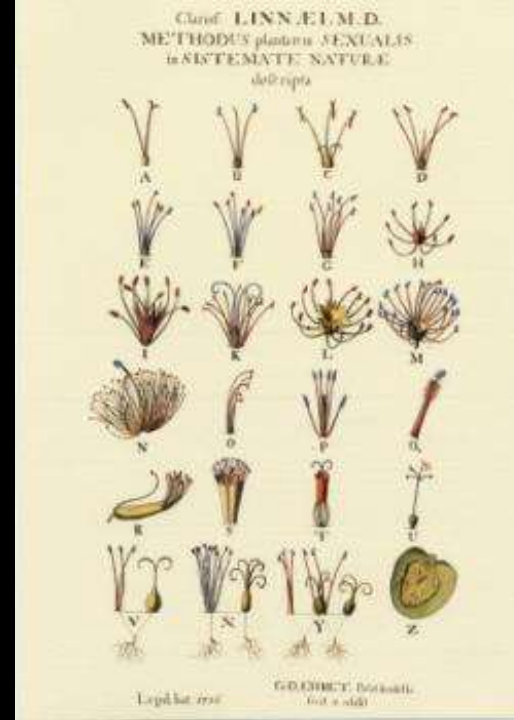
# The “Sexual System” Of Classification

Linnaeus had become convinced of the idea that all organisms reproduce sexually. As a result, he expected each plant to possess male and female sexual organs (stamens and pistils), or “husbands and wives,” as he also put it. His “sexual system” of taxonomy used the flower and its reproductive parts to structure the taxonomy, and it focused on “essential” diagnostic characteristics.

On this basis, he designed a simple system of distinctive characteristics to classify each plant. The number and position of the stamens, or husbands, determined the class to which it belonged, whereas the number and position of pistils, or wives, determined the order.

**Sexual Structures** - He divided them into classes by the number of "male genitals", the stamens (monandria, one stamen; diandria, two stamens), and then into orders by their pistils, the female "genitals": the supporting structure, the calyx, became the "nuptial bed". This meant, of course, that some flowers had far more than a single male...

**Scandalous** - This “sexual system” became popular because of its practicality but it also was attacked because of its erotic connotations.



# Classification and Natural Diversity - Biogeography

Comte de Buffon 1707–1788

French naturalist, mathematician, cosmologist, and encyclopedic author.

Buffon published thirty-six quarto volumes of his *Histoire naturelle* from 1749-88.

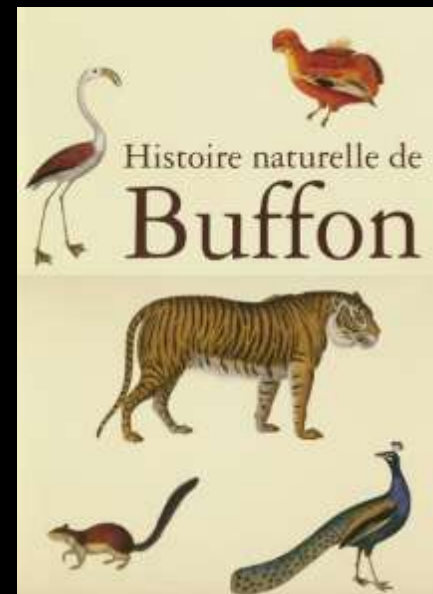
In the opening volumes of the *Histoire naturelle* Buffon criticized Linnaeus's taxonomical approach to natural history.

In the course of his examination of the animal world, Buffon noted that despite similar environments, different regions have distinct plants and animals, a concept later known as Buffon's Law. This is considered to be the first principle of biogeography.

## Classification - Total morphology to classify organisms

In contrast to Linnaeus, Buffon was less concerned with identification and more interested in vividly illustrating plenitude, diversity, and continuity of animal species.

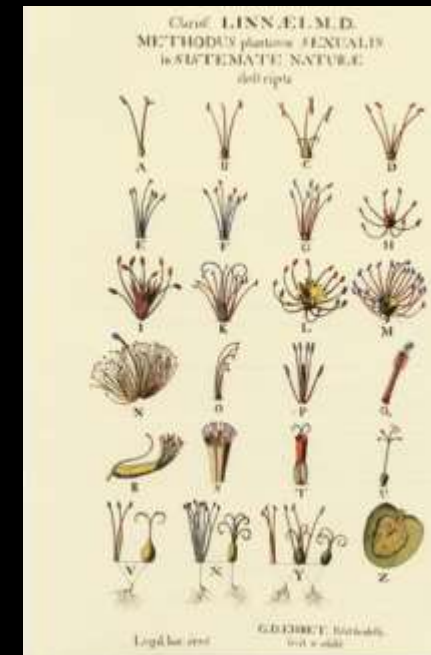
Buffon insisted we “must make use of all parts of the object” for classification, including internal anatomy, behavior, and distribution.





# Natural History Aristotle to Humboldt

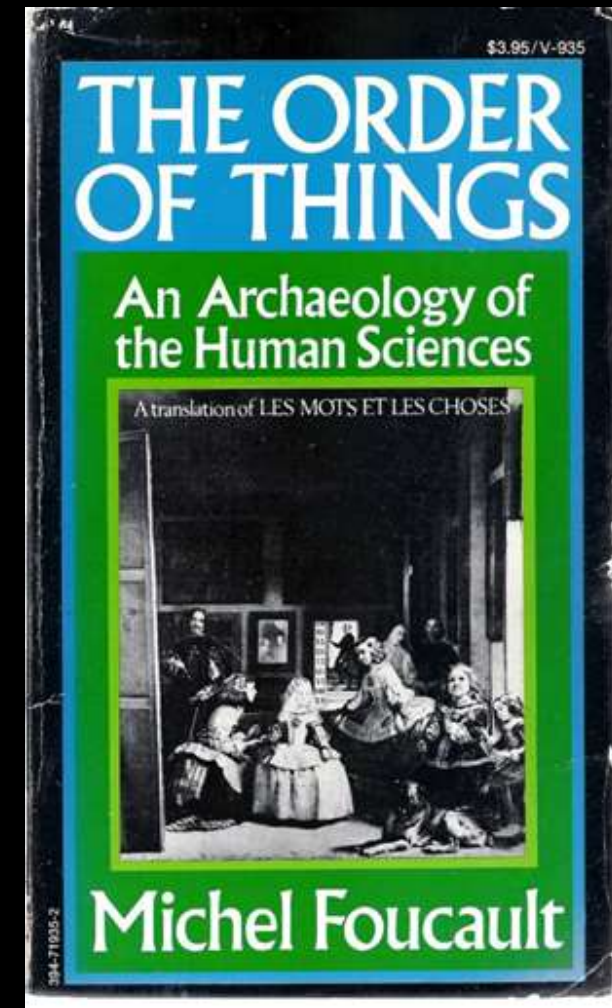
- Observation
- Description
- Encyclopedias
- Collecting
- Artists as Naturalists
- Classification
- Taxonomy



# Order and Change

Michel Foucault *The Order of Things* (1966)

- Foucault endeavors to excavate the origins of the human sciences, which have their root in "life, labour, and language", that is: biology, economics, and linguistics.
- Then it develops its central claim: that all periods of history have possessed certain underlying epistemological assumptions that determined what was acceptable as, for example, scientific discourse.
- Foucault develops the notion of episteme, and argues that these conditions of discourse have changed over time, from one period's episteme to another.
- The Classical episteme, characterized by representation, ordering, identity and difference
- The Renaissance episteme, which is characterized by resemblance and similitude
- Giving rise to the episteme of Modernism characterized by categorization and taxonomy

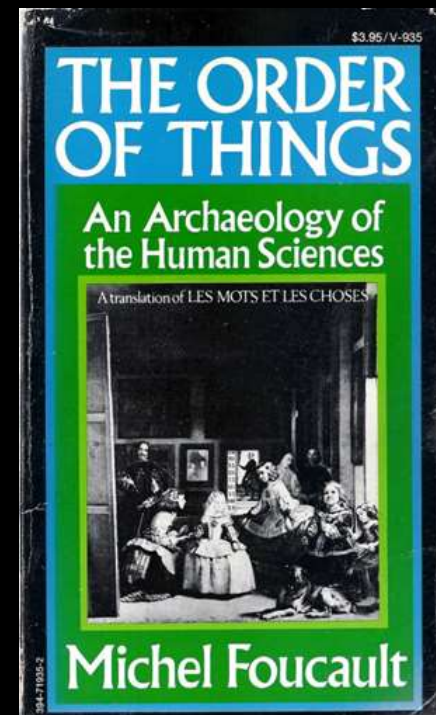
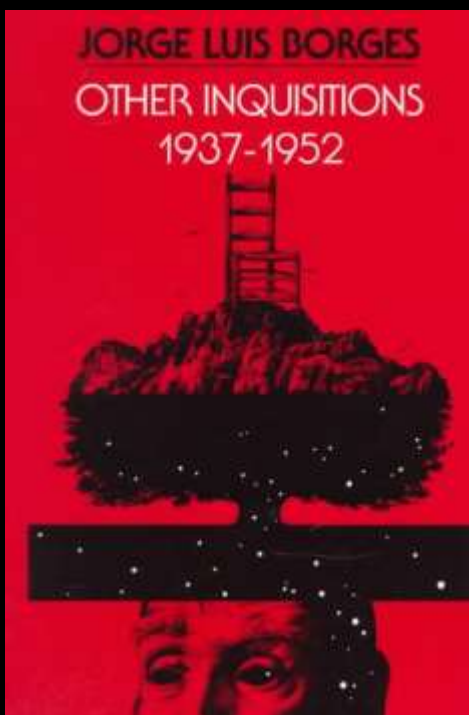


Michel Foucault *The Order of Things* (1966)  
Order and Change - The Same and The Other

The Celestial Emporium of Benevolent Knowledge

The Celestial Emporium of Benevolent Knowledge is a fictitious taxonomy of animals described by the writer Jorge Luis Borges in his 1942 essay "The Analytical Language of John Wilkins"

"This book first arose out of a passage in Borges, out of the laughter that shattered, as I read the passage, all the familiar landmarks of my thought—our thought that bears the stamp of our age and our geography—breaking up all the ordered surfaces and all the planes with which we are accustomed to tame the wild profusion of existing things, and continuing long afterwards to disturb and threaten with collapse our age-old distinction between the Same and the Other."



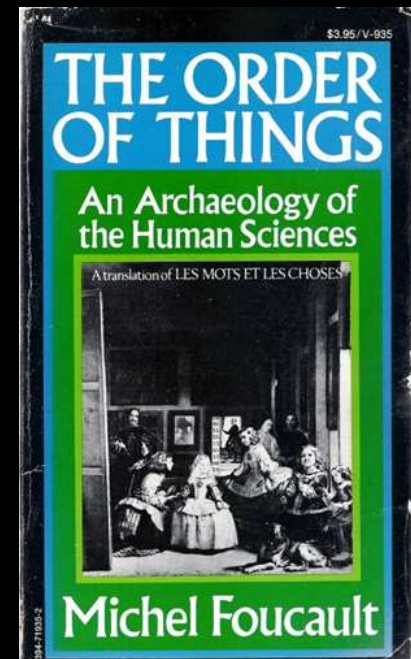
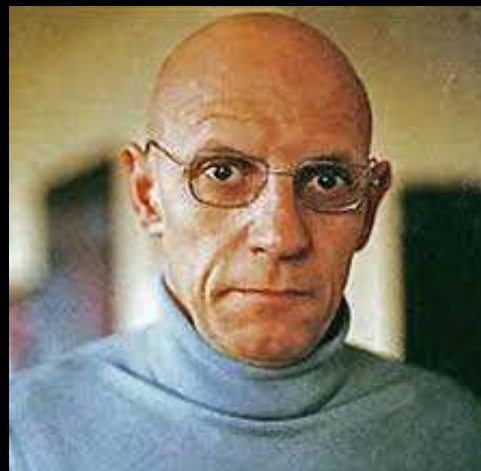
## Michel Foucault *The Order of Things* (1966)

### A Chinese Taxonomy

“This passage quotes a ‘certain Chinese encyclopedia’ in which it is written that ‘animals are divided into: (a) belonging to the Emperor, (b) embalmed, (c) tame, (d) suckling pigs, (e) sirens, (f) fabulous, (g) stray dogs, (h) included in the present classification, (i) frenzied, (j) innumerable, (k) drawn with a very fine camelhair brush, (l) et cetera, (m) having just broken the water pitcher, (n) that from a long way off look like flies’.

In the wonderment of this taxonomy, the thing we apprehend in one great leap, the thing that, by means of the fable, is demonstrated as the exotic charm of another system of thought, is the limitation of our own, the stark impossibility of thinking that.”

Borges concludes: "there is no description of the universe that isn't arbitrary and conjectural for a simple reason: we don't know what the universe is".

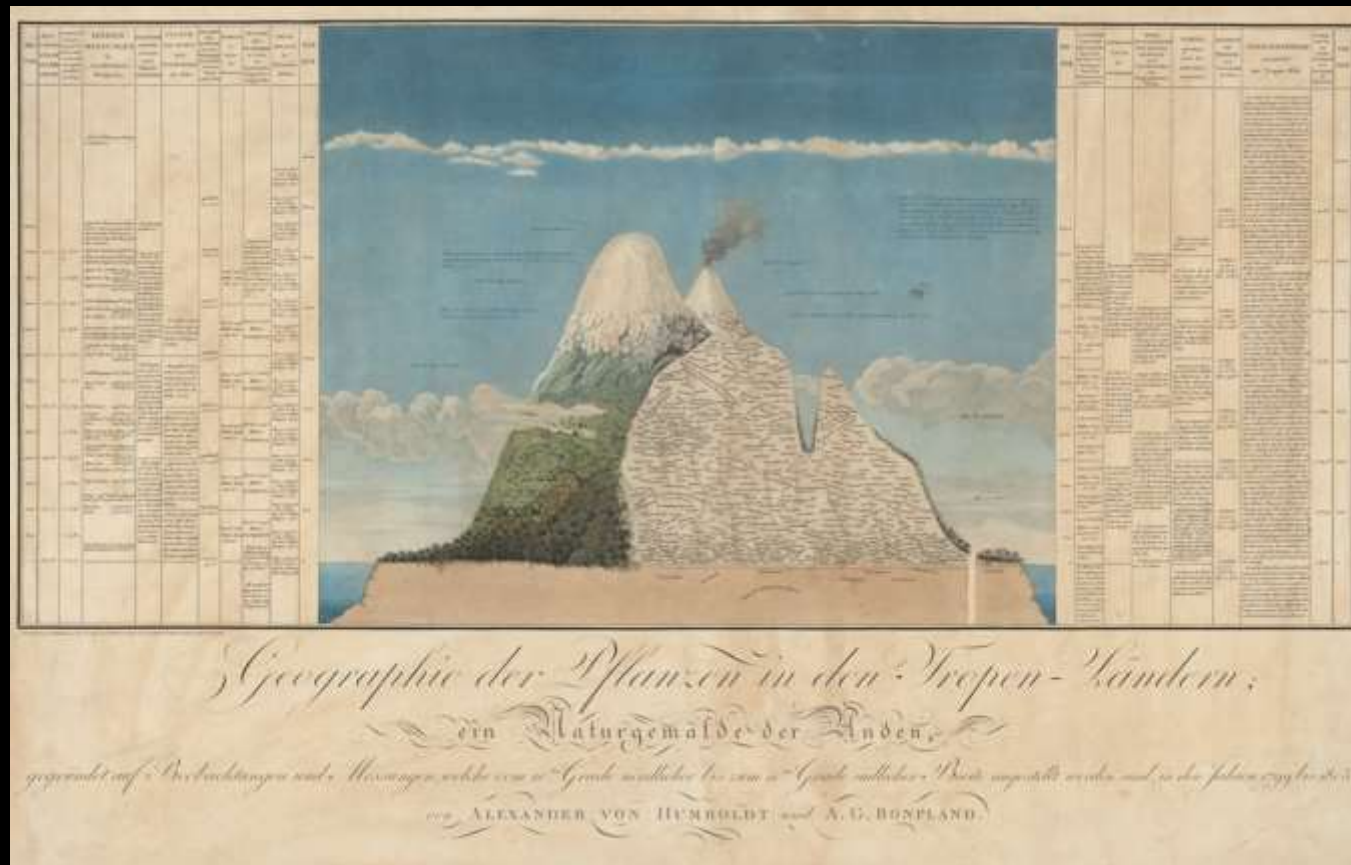
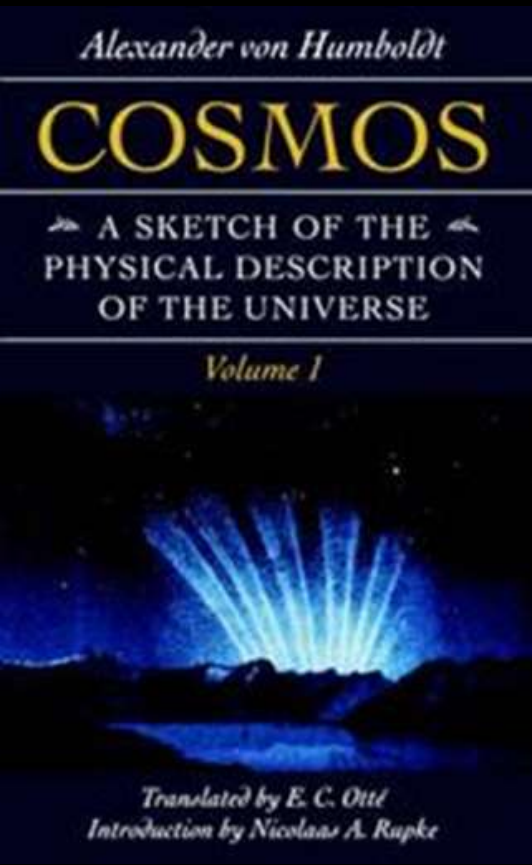


# Humboldtian Cosmos - A Vision of the Unity of Nature

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

