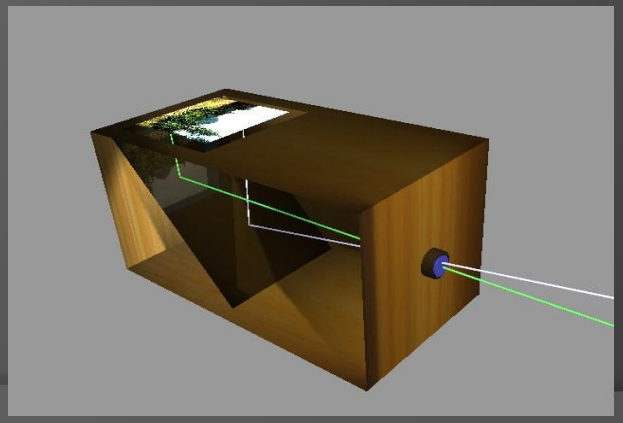
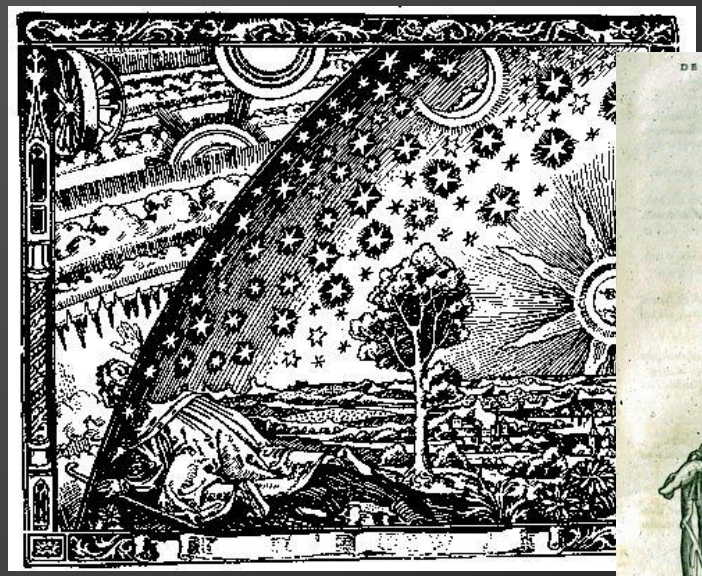
THE HUNTINGTON

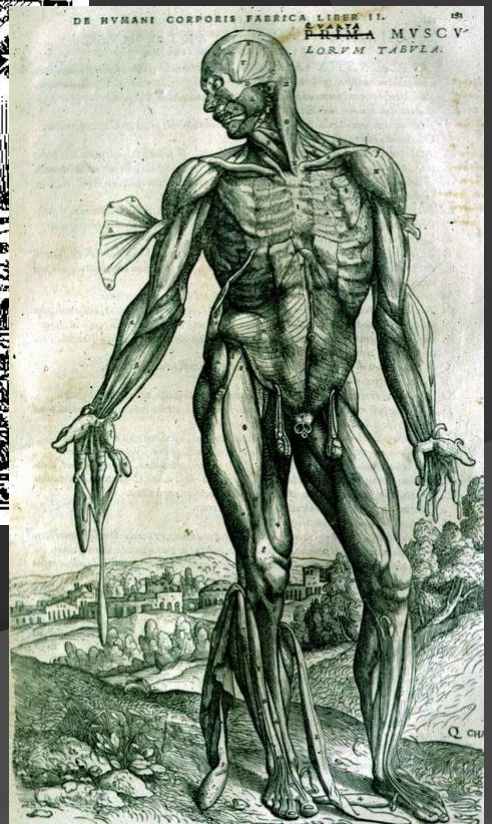
Library, Art Collections, and Botanical Gardens

History of Science School Program

Week 2

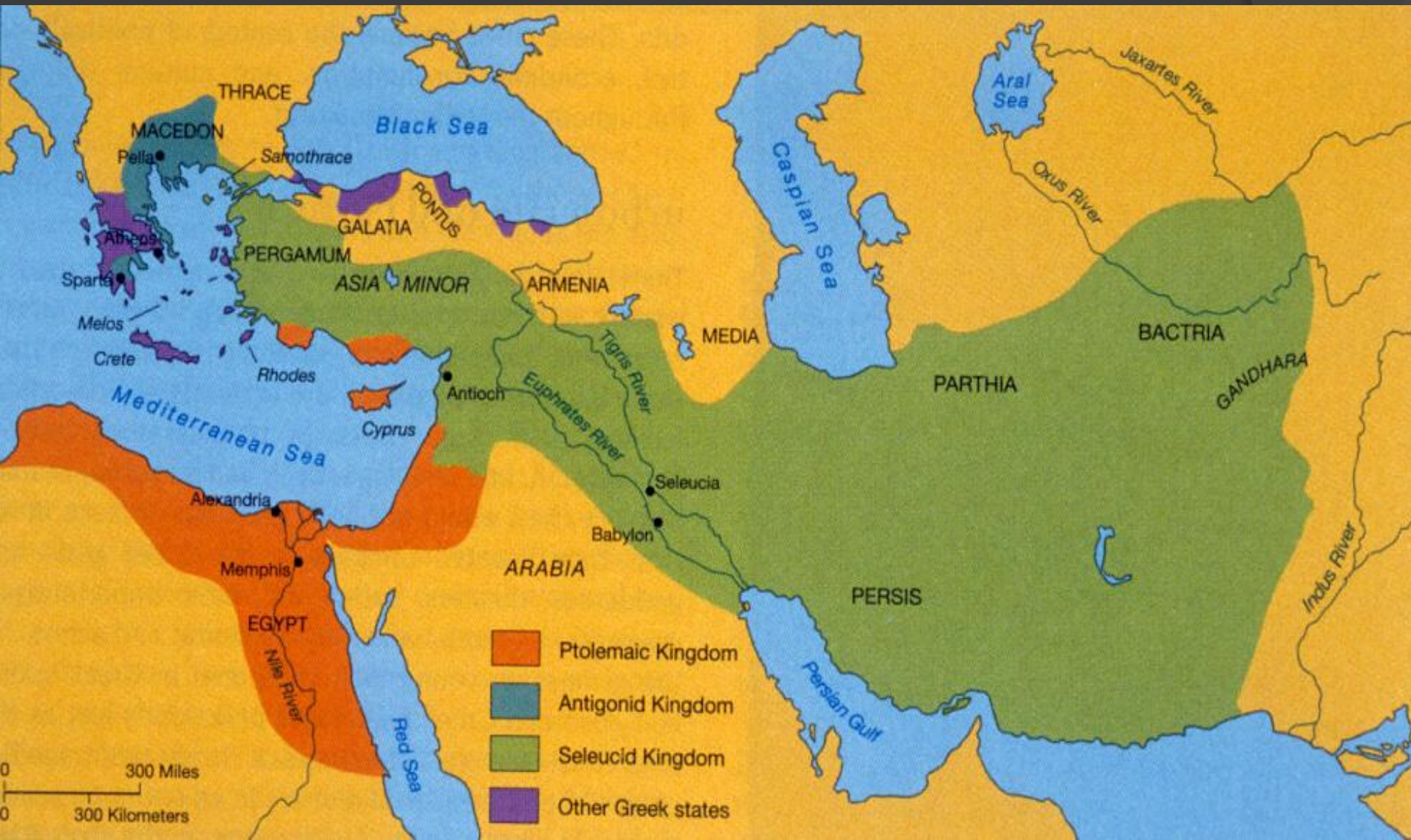






The Hellenistic Period

(Review)



(Review)

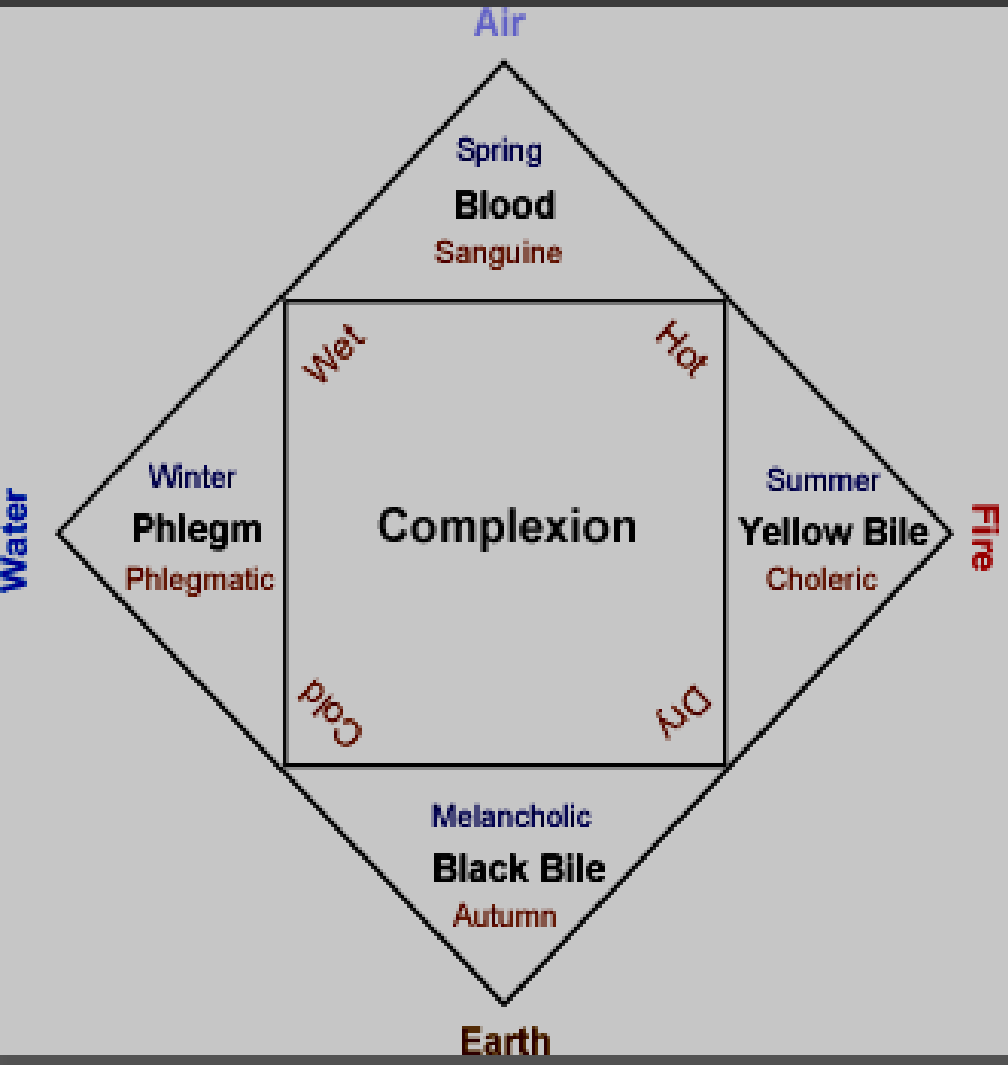
Hellenistic civilization represents a fusion of the Ancient Greek world with that of the Near East, Middle East and Southwest Asia.

1. A massive inter-penetration of Greek and non-Greek ideas.
2. The increasing specialization of the sciences.
3. The development of new centers of research (especially Alexandria) and institutions (such as Museum and Library).
4. The increase in kingly patronage

- **Distinguished Men of science in the Hellenistic Period (Review)**
- Eratosthenes (d. *ca. 195 BC):* Calculated circumference of earth
- Euclid, *fl. 295 BC:* Wrote: *Elements*, 13 books
- Apollonius (*ca. 260-200* BC) Did for conic sections what Euclid did for plane geometry; Wrote *On Conic Sections* in 8 books, contained about 400 propositions
- Aristachus of Samos (*ca*. 310-230 BC) , wrote: *On the Sizes and Distances of the Sun, Moon, and Earth*
- Hipparchus of Nicaea (192-126 BC) , calculated the length of the year to within 6.5 minutes and discovered the precession of the equinoxes. His star catalogue contained about 850 stars whose positions were mathematically predictable.
- Ptolemy of Alexandria (*ca*. 100-170 AD) wrote the *Almagest* which contains mathematical theories of the motions of the Sun, Moon, and planets.
- Archimedes of Syracuse (*ca. 287-212 BC)* wrote: *On Floating Bodies, Sand Reckoner, On Sphere Making*
- Strabo of Amasia (*ca. 64 BC-25 AD),* wrote: *Geographia* in 16 books
- Galen of Pergamum (AD 129 – 200/217). His works cover a wide range of topics, from anatomy, physiology, and medicine to logic and philosophy

Medieval Medicine

See the next slide for explanations



Sanguine(hot,wet)	Prone to optimism
Phlegmatic (cold, wet)	Prone to apathy
Melancholic (cold, dry)	Prone to sadness
Choleric (Hot, dry)	Prone to anger

The human body was assumed to be filled with four basic fluids called the four humors: black bile, yellow bile, phlegm, and blood.

Humors were closely related to the four elements: earth, fire, water and air. Earth was present in the black bile, fire in the yellow bile, water in the phlegm, and all four elements were present in the blood.

An ideal temperament involved a balanced mixture of the four qualities. Any inequality or imbalance in humors caused diseases, and the job of a physician was to bring back the humors to a balanced situation.

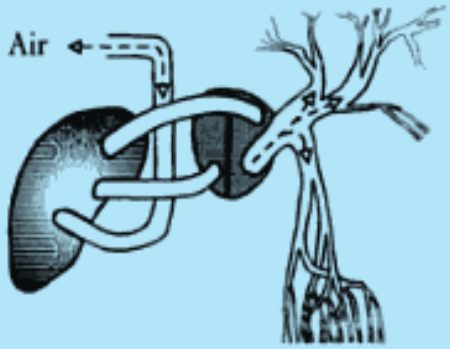
Physicians used a combination of drugs and ointments (mostly herbal) which were described in texts called *Materia Medica*. Galen's theory of medicine was dominant in the education of medicine during the medieval period.

Galenic Physiology :

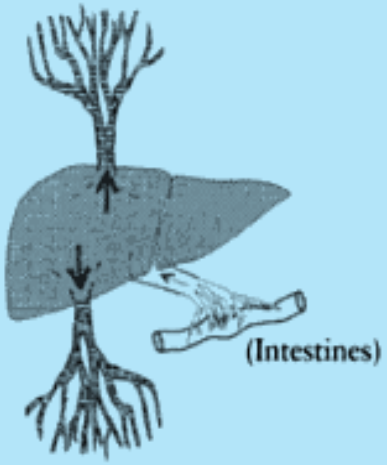
Internal organs are divided into three distinct subsystems governed by three different "spirits" functioning in the human body:

- A psychic essence permeating the brain and nerves,
- A vivifying arterial spirit arising in the heart, and
- A nutrifying venous spirit originating in the liver.

Brain/Nerves distribute "Animal Spirits"



Heart/Arteries distribute "Vital Spirits"

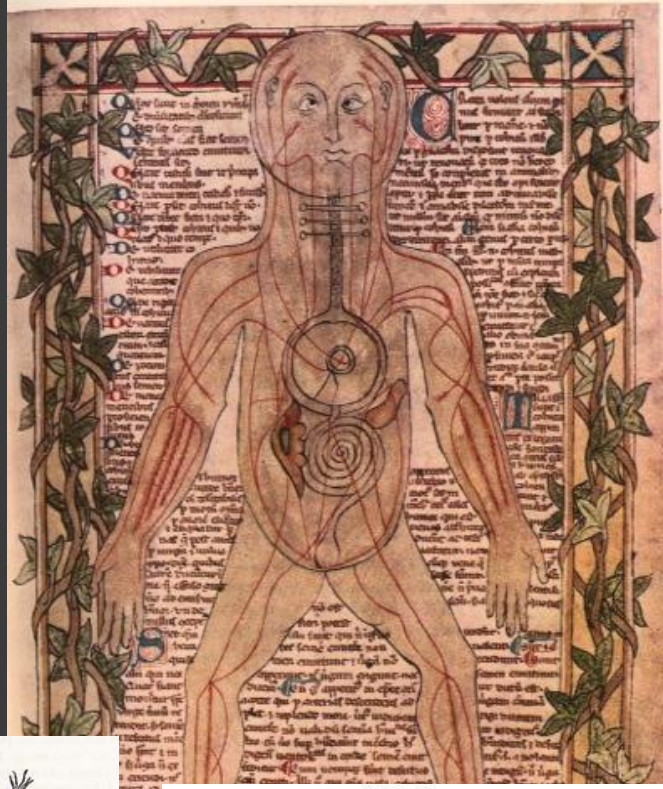


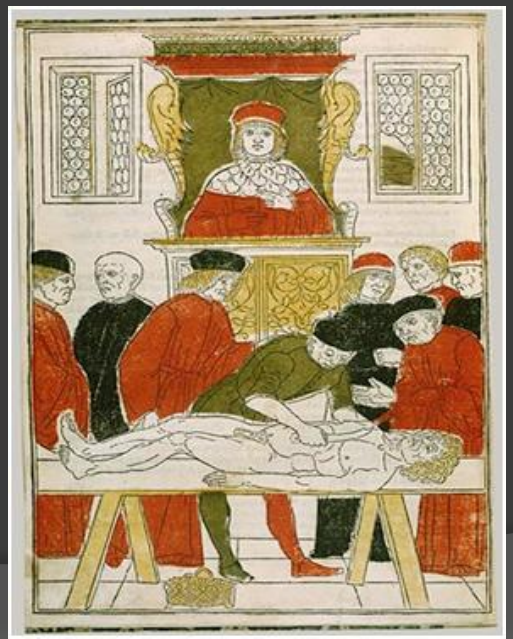
Liver/Veins distribute "Nutrifying Spirits"

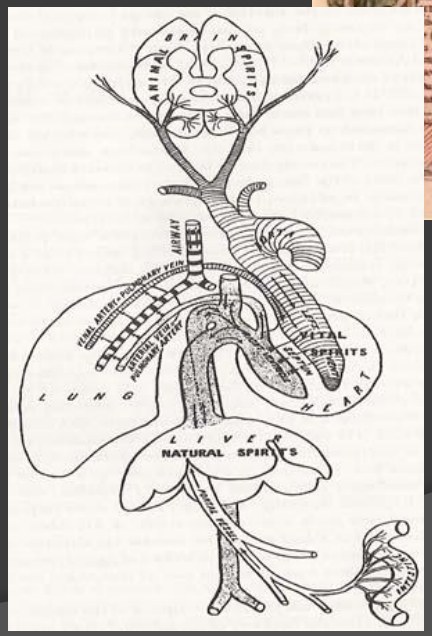
Dissection was not allowed in Ancient Greece, but there are reports that some Greek doctors performed dissections in Alexandria.

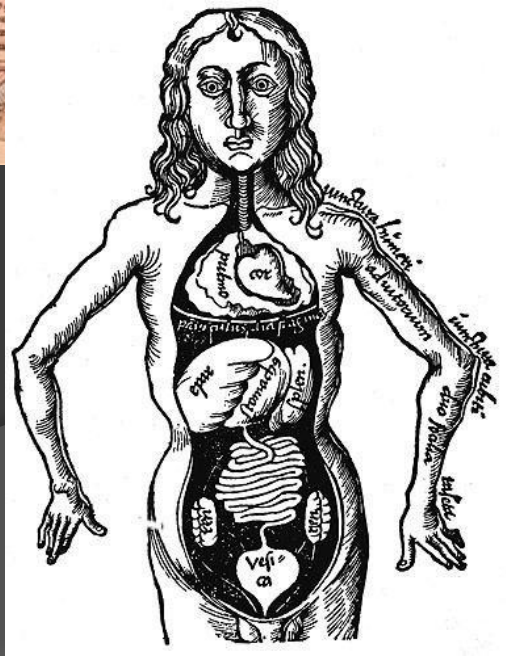
Romans prohibited dissection. That is why Galen had to practice on pigs, dogs and apes.

In the entire Medieval period, dissection was generally forbidden, except in some universities surgeons were allowed to dissect the body of criminals to show students the internal organs. Students were not allowed to perform their own dissections.





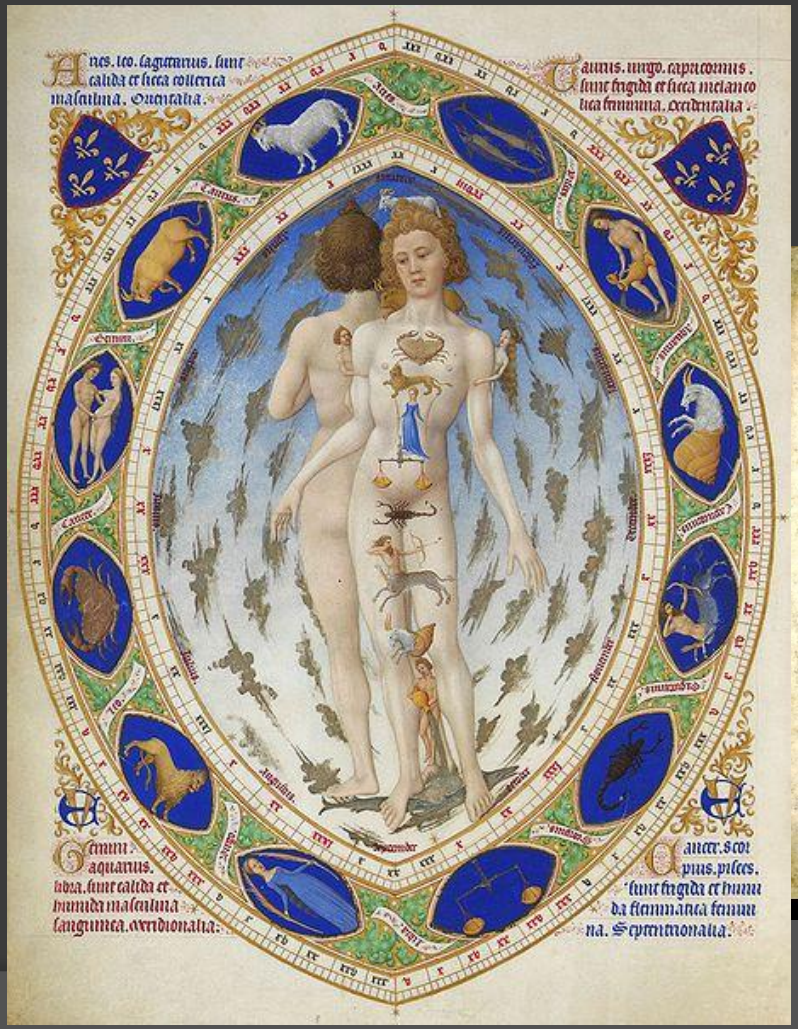




Materia medica

Collected knowledge about the therapeutic properties of any substance (mostly herbal) used for healing

Medicine and Astrology: the concept of macrocosm-microcosm



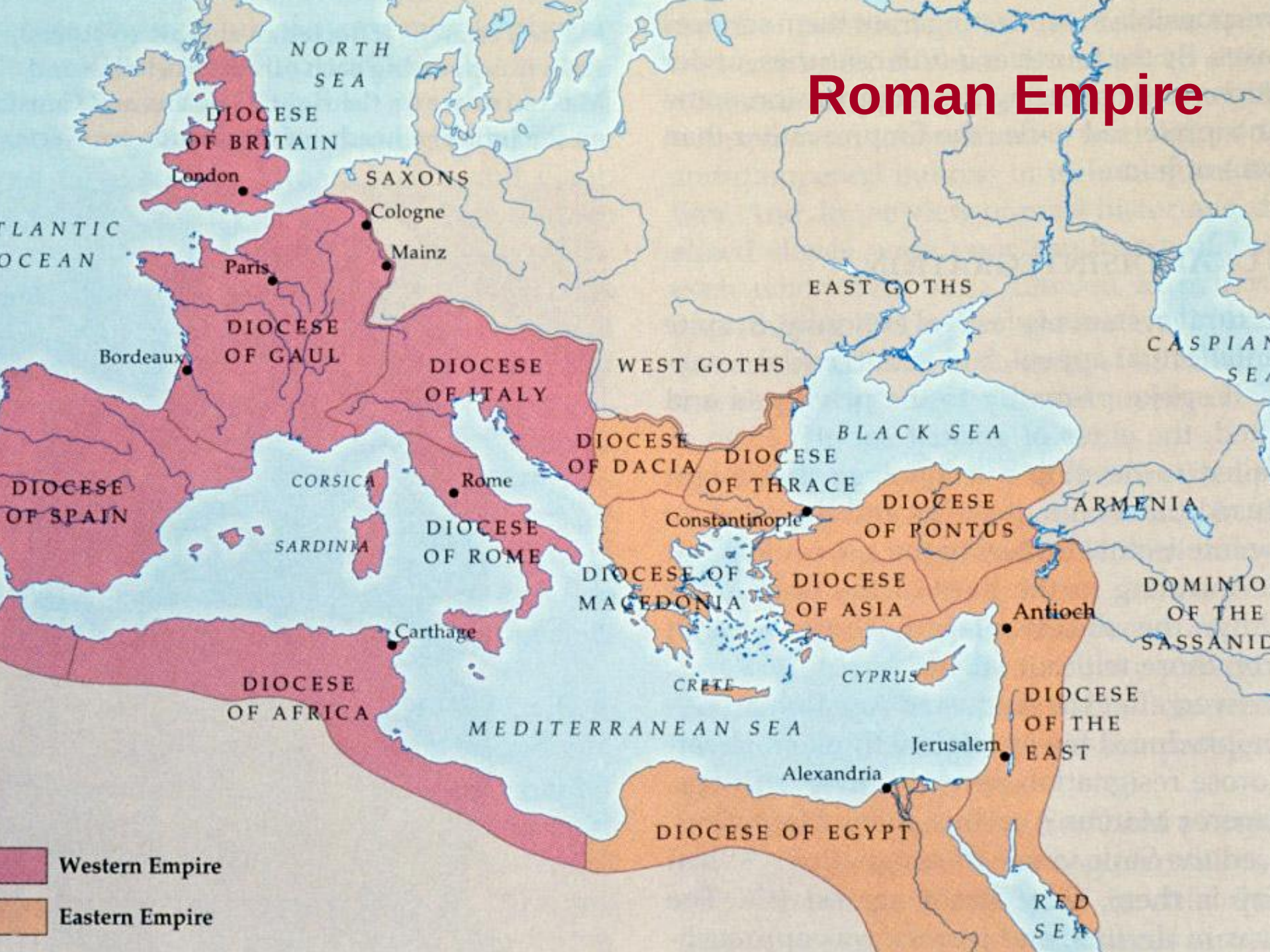
A Page from Dioscorides' *De Materia Medica*

Hellenic Tradition vs. Hellenistic Tradition

- **Hellenic: More philosophical and qualitative**
  - **[Socrates, Plato, Aristotle, ….]**

- **Hellenistic: Quantitative, Mathematical,**
  - **[Ptolemy, Archimedes, Euclid, Galen, ….]**

  - **Major events (From the 2nd century BC to the 3rd century AD):**
    - **Culmination of the Hellenistic Tradition**
    - **Rise of the Roman Empire**
    - **The rise of Christianity**
    - **Decline of the Roman Empire**
    - **Gradual decline of scientific activities**

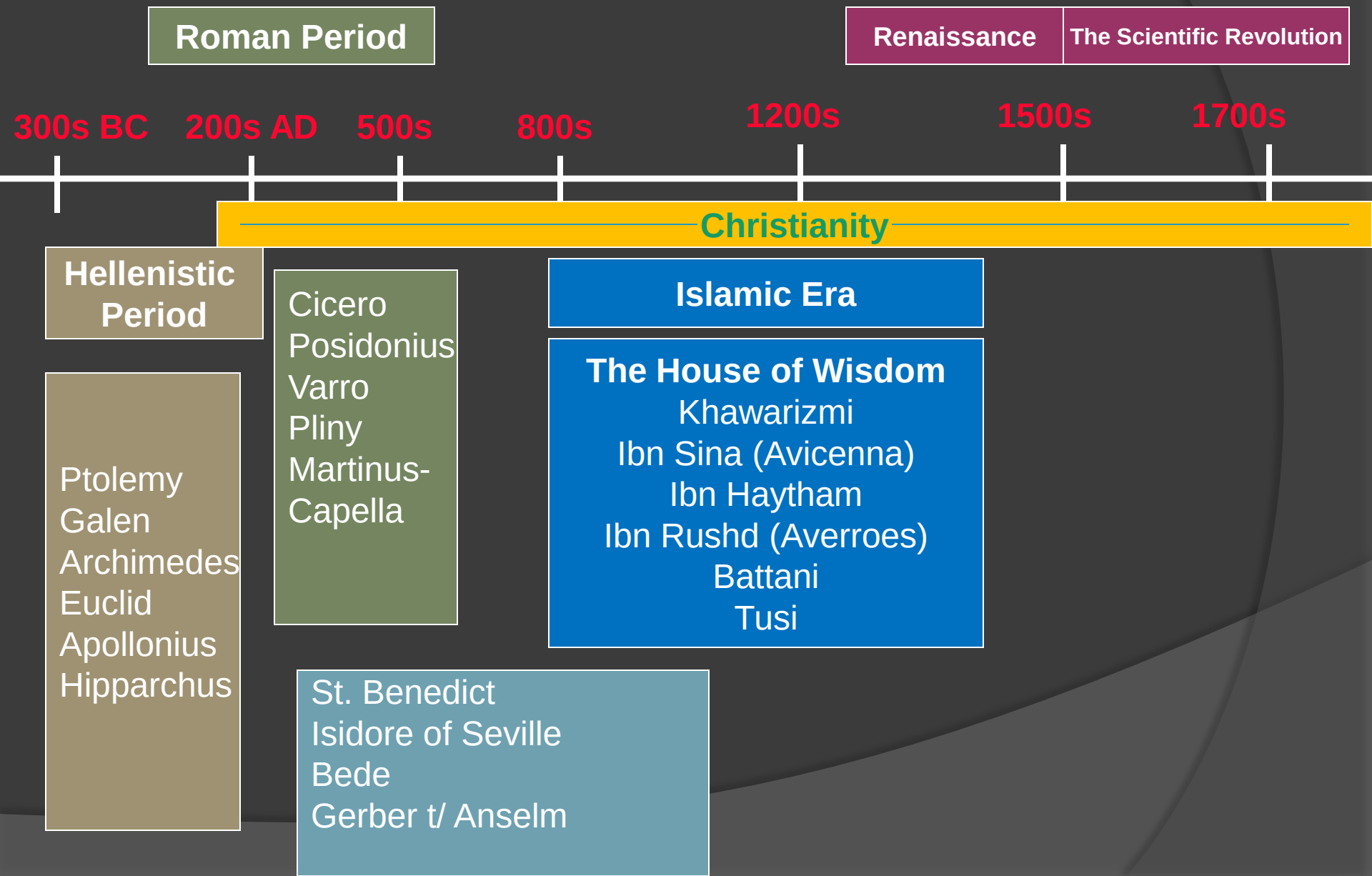

Roman Empire
NORTH SEA
DIOCESE OF BRITAIN
London
SAXONS
Cologne
Mainz
Paris
DIOCESE OF GAUL
Bordeaux
DIOCESE OF ITALY
WEST GOTHS
EAST GOTHS
BLACK SEA
DIOCESE OF DACIA
DIOCESE OF THRACE
DIOCESE OF SPAIN
CORSICA
Rome
SARDINIA
DIOCESE OF ROME
Constantinople
DIOCESE OF PONTUS
ARMENIA
DIOCESE OF MACEDONIA
DIOCESE OF ASIA
Antioch
Carthage
DIOCESE OF AFRICA
CRETE
CYPRUS
MEDITERRANEAN SEA
DIOCESE OF THE EAST
Jerusalem
Alexandria
DIOCESE OF EGYPT
RED SEA
Western Empire
Eastern Empire

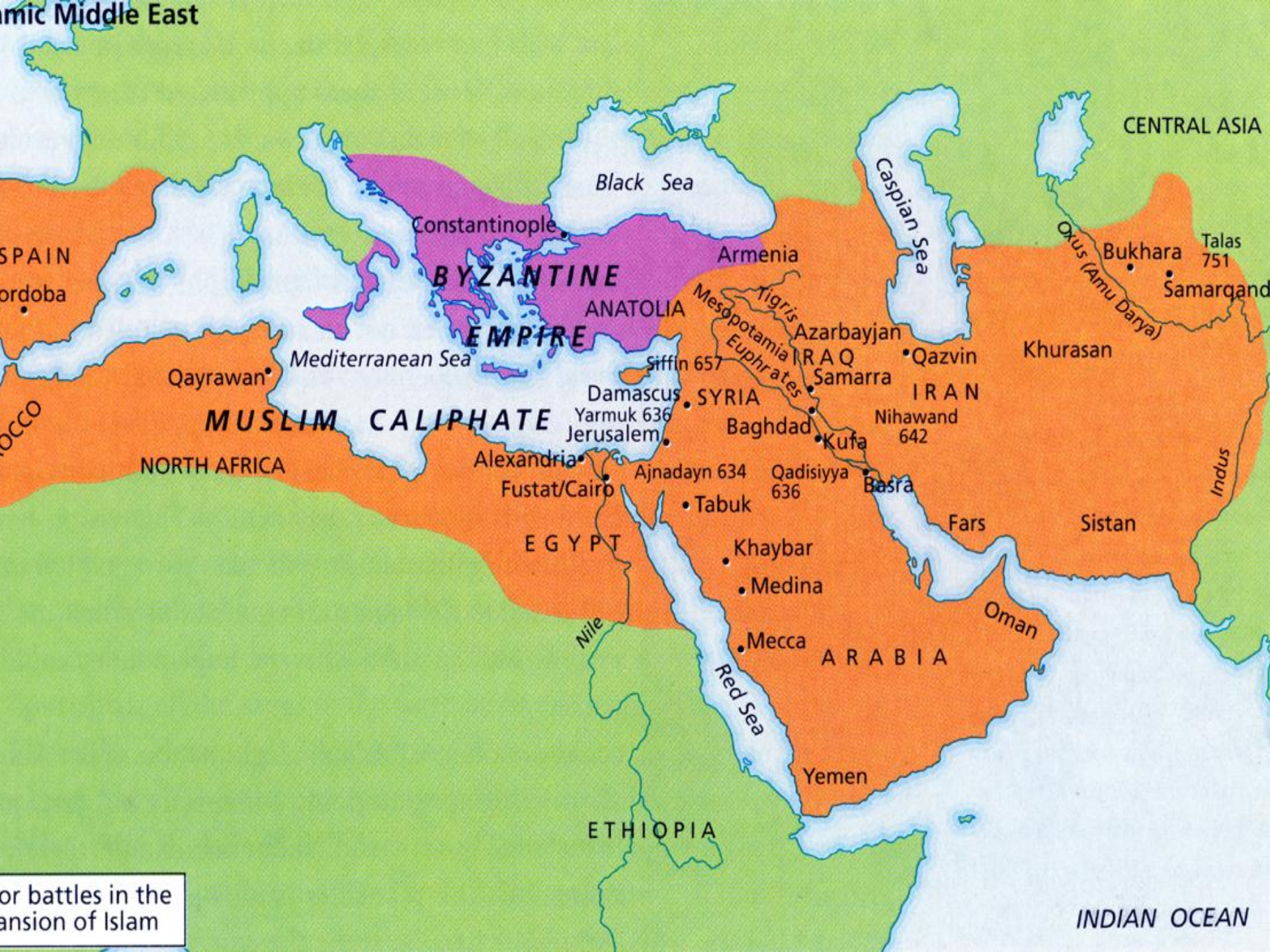
Compared to the Hellenic and Hellenistic periods, no major development happened in science (except in medicine) and philosophy in the Roman period.

Romans were the greatest technologists and engineers of the ancient world.

Romans contributed to art, architecture, urban development, warfare and medicine.

- **The West's loss of ancient science occurred in two stages:**
  - **First, a slow decline in the quality and quantity of scientific activities [from 2nd century AD, during Roman hegemony]**
    - **Commentaries, Encyclopedias, General texts**
  - **The second, a genuine disappearance of traditional learning [after the fall of the Roman Empire, and specially after the Islamic invasions]**
    - **Europeans were deprived of the documents in which the ancient learned tradition was embodied.**
- **During the centuries when European learning reached its nadir, there was a great renaissance of science in Islam**


Roman Period
Renaissance
The Scientific Revolution
300s BC
200s AD
500s
800s
1200s
1500s
1700s
Christianity
Hellenistic Period
Ptolemy
Galen
Archimedes
Euclid
Apollonius
Hipparchus
Cicero
Posidonius
Varro
Pliny
Martinus-Capella
St. Benedict
Isidore of Seville
Bede
Gerber t/ Anselm
Islamic Era
The House of Wisdom
Khawarizmi
Ibn Sina (Avicenna)
Ibn Haytham
Ibn Rushd (Averroes)
Battani
Tusi


amic Middle East
SPAIN
ordoba
OCCO
Black Sea
Constantinople
BYZANTINE
EMPIRE
ANATOLIA
Armenia
Caspian Sea
CENTRAL ASIA
Oxus (Amu Darya)
Bukhara
Talas
751
Samarqand
Mediterranean Sea
Qayrawan
MUSLIM CALIPHATE
NORTH AFRICA
Siffin 657
Damascus
SYRIA
Yarmuk 636
Jerusalem
Alexandria
Fustat/Cairo
EGYPT
Mesopotamia
Tigris
Euphrates
IRAQ
Azarbayjan
Qazvin
Samarra
Baghdad
Nihawand
642
Kufa
Ajnadayn 634
Qadisiyya
636
Basra
Tabuk
Khaybar
Medina
Mecca
ARABIA
Red Sea
Nile
IRAN
Khurasan
Fars
Sistan
Indus
Oman
Yemen
ETHIOPIA
INDIAN OCEAN
or battles in the
ansion of Islam

- **Translation Movement, from the 8th to the 10th centuries at the *House of Wisdom* in Baghdad**

- **Almost all Hellenic and Hellenistic texts were translated to Arabic: *Almagest* [it is an Arabic title!], Aristotle's *Logic*, *On the Heavens*, *Meteorology*, …. Galen's works, Euclid's *Elements*, Apollonius' *Conic Sections*, etc.**

- **Muslim scholars not only translated Greek and Hellenistic works, but also wrote numerous commentaries to explain or criticize those them. They made new observations, solved difficult mathematical equations, developed trigonometry, and built several observatories and hospitals.**
- **The decline of scientific activities among Muslims, coincided with the ascend of intellectual activities in Europe.**

- Europe after the 12th century
  - Improved agriculture
  - Strong economy
  - Trade with other states, especially Muslims
  - Development in educational system
  - Need to learn practical knowledge, such as arithmetic, medicine, astronomy
  - **Translation Movement**

The earliest translation from the Arabic to Latin – several treatises on mathematics and the astrolabe – were made in the tenth century in Spain.

- **Translation:**
  - Arabic to Latin
  - Greek, Syriac (ancient languages) to Latin

  - Expansion of knowledge + Educational reform>>
    - Establishment of the first universities in Europe (University of Paris: 1150; Oxford: 1167; Cambridge: 1209; Padua: 1222…)

Development of the critical and combative philosophical tradition known as scholasticism.

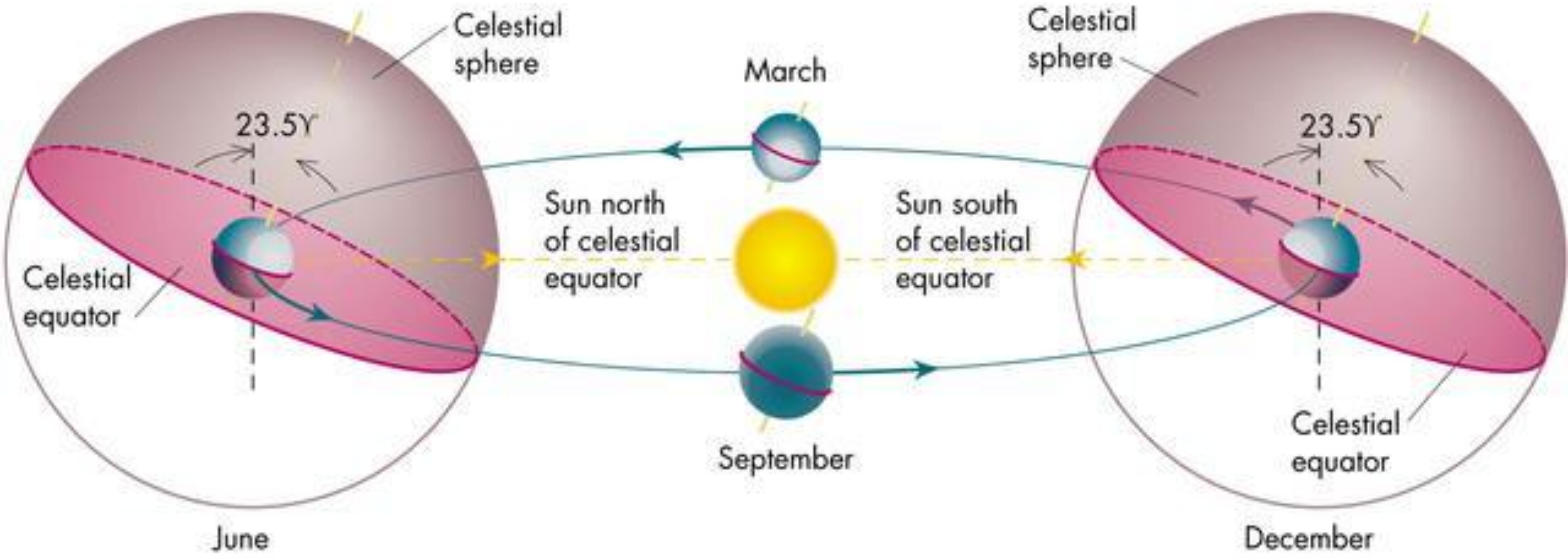
- **Aristotle's scholastic critics developed important alternatives for some of his doctrines.**

- **At the Threshold of the Scientific Revolution**

- **The Renaissance: Humanism and Science**
- **Better economy: trade with other states, especially with the East**
- **Introduction of the printing press, and the compass**
- **Criticism of the authorities in philosophy, science and religion**
- **The discovery of the new continent**
- **Revolution in astronomy: The heliocentric model**
- **New discoveries in astronomy rejected Aristotle's cosmology**

Copernican Revolution:
The sun is at the center of the planetary motions.

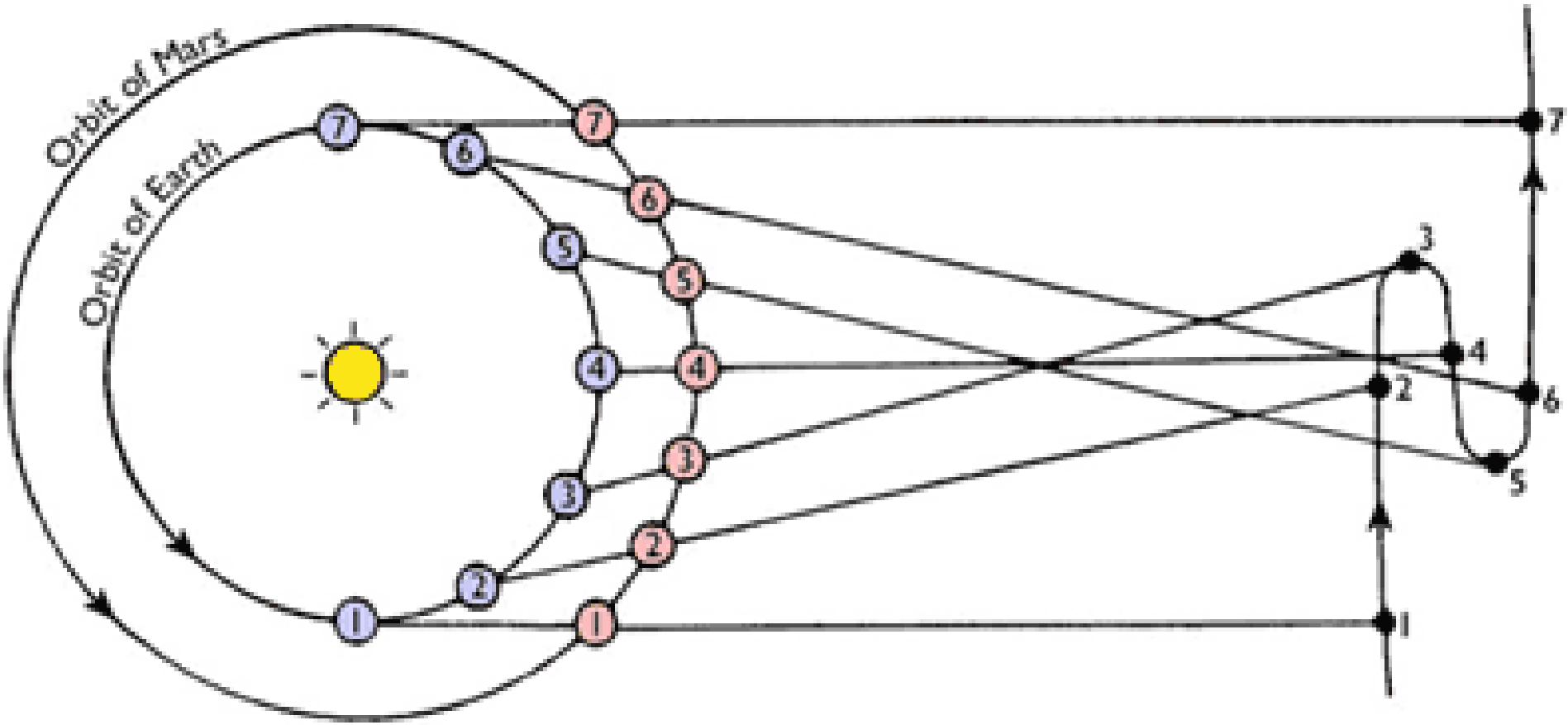
De revolutionibus orbium coelestium (*On the Revolutions of the Heavenly Spheres*)
1543



Copernican Revolution

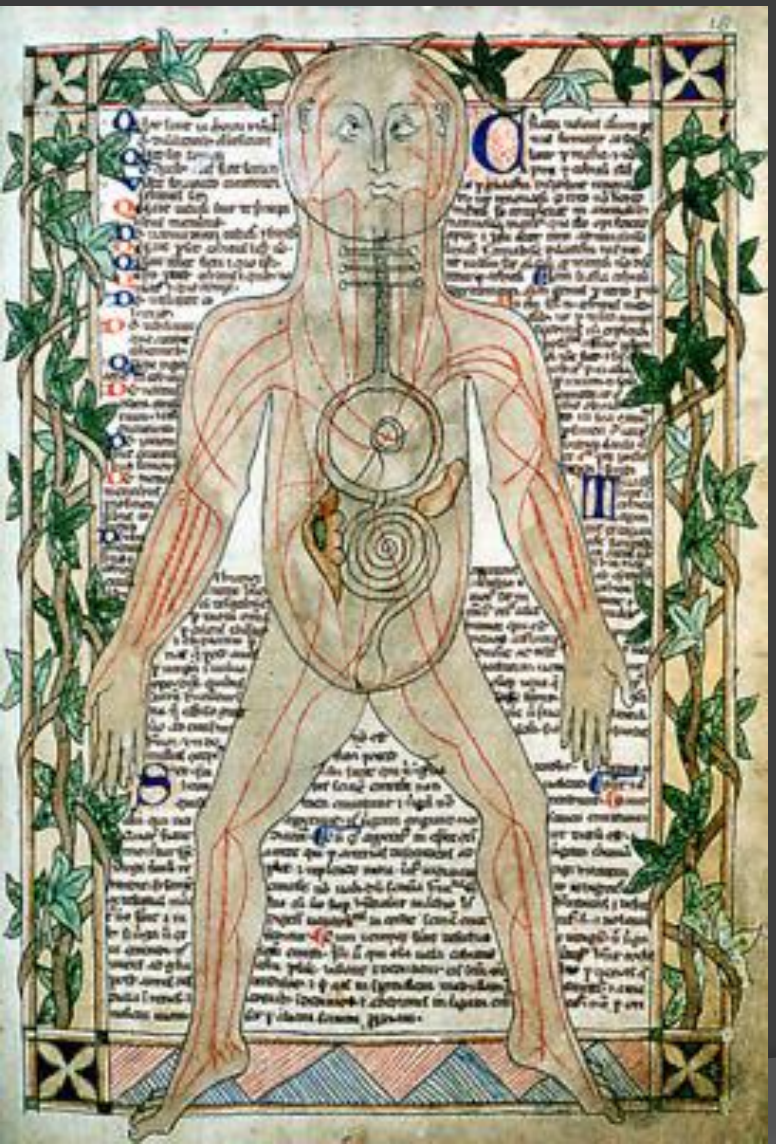
Copernican Revolution:

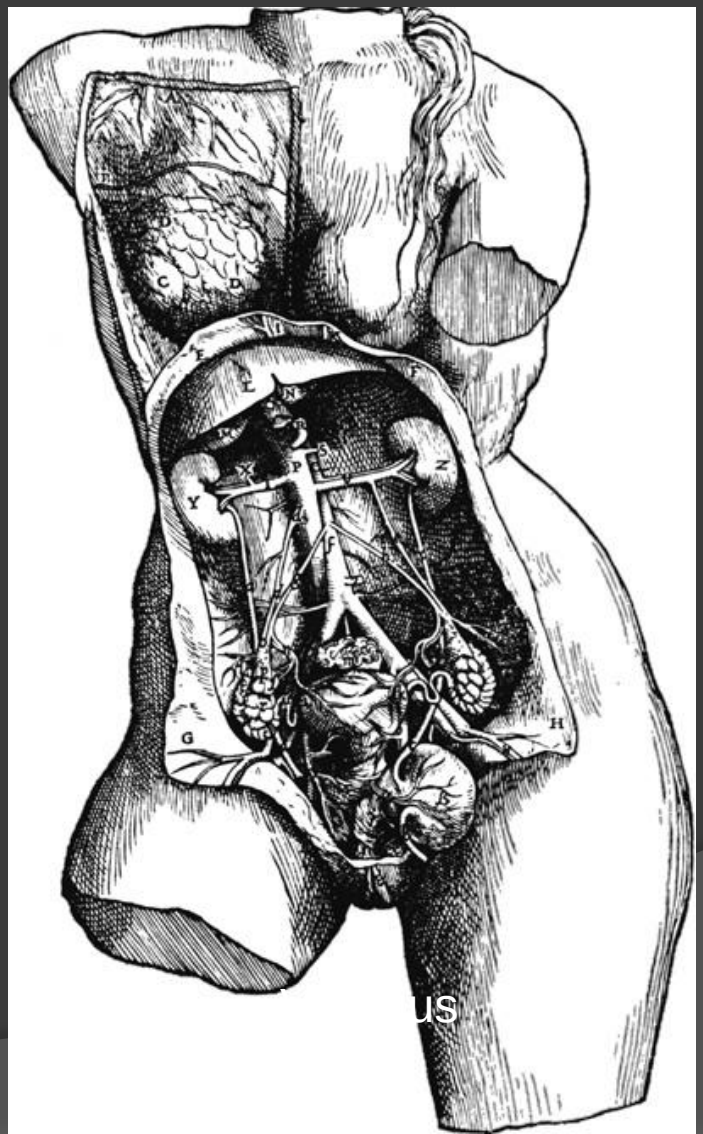
Copernicus solved the long-lasting problem of the retrograde motion

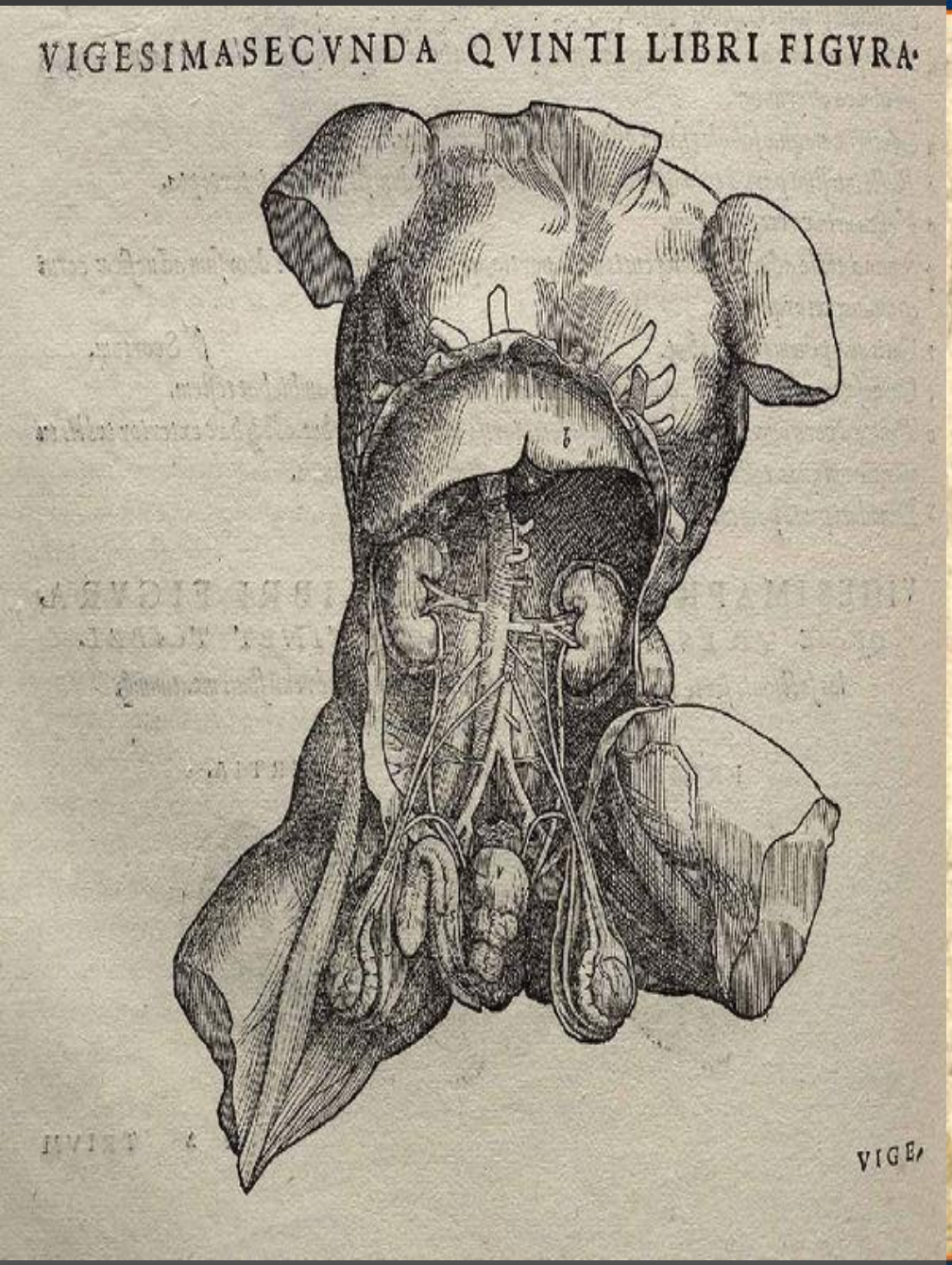


Revolution in Anatomy:

Andreas Vesalius: ***De humani corporis fabrica*** (*On the Workings of the Human Body*), 1543







PRIMA FIGVRA EARVM QVAS OSTENDENDIS MVSCVLIS POTISSIMVM PA

RAVIMVS. IN CVIVS DEXTRO LATERE MVSCVLI MOX SVB CVTE RECONDITI, ANTERIORI IN

facie conspicuntur: in sinistro autem illi resecti obuij sunt, qui in dextero latere apparentibus proxime succumbunt. Vt uerò præsentem sectionis ordine proponere incepimus, humi oculis musculos, aut

figura redderetur copiosior, eorum quæ caluaria complectitur ima

characterum index docebit, delineantes.

DEXTRI LATERIS CHARACterum Index.

A,A Dura cerebri membrana ita apparens, ut inter secundum caluariæ superioris partis sectionis ordine ablata, ostenditur.

B,B Duræ membranæ ossa secundum ipsius latera serrato anfractuosoq; modo digesta.

C,C Tenuis duræ membranæ sinus hic secundum longitudinem elaborata cernitur.

D Circulus ille ex ossibus durioris.

E Musculosa falcibus frontis cutem mouens.

F Palpebrum superiorum attollens musculus.

G Musculus eundem palpebrum deorsum ducens.

H Hic duo musculi super dicta ossa connguntur.

I Temporalis musculi fedes.

K Musculus non penitus a insignita in nasi alam, altera uero à radicina in superiori labrò inserta.

L Cartilaginosa alterius nasi ossi proxima.

M Dextra nasi ala.

N Musculus à malis in superius labrum inserens.

O Musculus ex carnea constitutus membrana, & labra & buccas mouet, ex a, b, c, d circumscriptus. uerum à primum sibi nasus in altero latere secundi maxillam inferiorem mouentium musculi.

P Brachium mouentium secundus hic anteriori sua fibi a, b, c circumscriptus.

Q Brachij mouentium primus, a, b, c, d circumscriptus.

R Pectoris ossi pars; brachium mouentis.

S,S Stabij S,S insignitæ, ex inter illas cha racteres media musculi thoracem mouentium secundi ossi pectoris.

T Deorsum obliquè in anteriorem fibras suas ducens abdominis musculus, a, b, c, d, e circumscriptus.

V Tellis una cum seminalibus uasis tunica, quam ipsi peritonæum offert, adhuc obductus.

X Primi caduum flectentium.

Y,Y Posteriora caduum flectentium.

Z Cubiti extensorium primi pars.

a Radium in pronationem agentium primus.

b Radium in supinationem agentium primus.

A Pectoris tertij brachiale mouentium.

I Brachiale mouentium primus.

m Latus tendinem sub interna manus cute producit, ac a, b circumscriptus.

n Brachiale mouentium secundus.

o,o,o Hi interualla primos digitos mouentia se offerit.

p Digitos mouentium ut gastrocnemij.

q Pectoris maioris primum pollicis os flectentium.

r Digitos mouentium ut gastrocnemij.

s Primi cum ossibus se inuicem circumdantes.

t Primus tibiam mouentium, a, b circumscriptus.

u Sextus tibiam mouentium, a, b, c, d circumscriptus.

x Glutæus in inguine nascens distributioni profecit.

y Portio sextum femur mouentium.

z Portio quinti femur mouentium, cui nil uasa communicant.

& Portio secundi tibiam mouentium, cuius insertio e regione tertij autem tibiam agentis insertio d notatur.

2 Portio noni tibiam mouentium.

A Portio octaui tibiæ mouentium.

aa Nulla externis ossibus fides.

b Sextus pedem mouentium, a, b circumscriptus.

c Portio decimi quinti digitos pedis mouentium.

d Portio & tendines decimiquarti digitos pedis mouentium.

e Tendo noni pedem mouentis.

aaa Hæ obliquè prorepunt tendines decimisexti digitos mouentium.

bb Ligamentum transuersum in tibiæ anteriori sede positum hic dissectum cernitur ut & ligamenta interna malleolum & talum conflcia, & y, y, y notata.

c Primus pedem mouentium.

f Tendo tertij pedem mouentium.

o Portio quarti pedem mouentium.

m Secundi digitos pedis mouentium portio.

r Quinti pedem mouentium portio.

s Decimiseptimus digitos mouentium.

SINISTRI LATERIS CHARACterum Index.

A,A In hac capitis parte sectionis ordine durum cerebri membranam à tenui remouimus, hic q; sinum cerebri notauit membrana.

B,B Vasa in tenui membrana ex cerebro duræ mallearum sinu deprompta.

C Duræ membranæ pars deorsum à tenui reflexa.

D Duellum ossium unum ex ossis pars duræ membranæ latera exacte complectitis unicum membranarum productarum unus.

E Nervus superioris obliqui maxillæ, à minori ortus parte nervorum cerebri radice.

F Musculus in buccis positus, ac buccas labrag; mouentium in alterolatere quartus.

G Labra mouentium tertius.

H Primus ossi o reflexæ propriorum.

I Septimi pars capitis mouentium alary.

K Portio secundi scapulam mouentium.

L Portio tertij scapulam mouentium.

M Aduersus, os o reflexæ deorsum in latera trahentium portio.

N Clauicula.

O Primus thoracis mouentium.

P Hi ab eorum nervorum copia exillam prodi.

Q Pectoris ossis anteriores fedes hoc latere breuiter ostendunt.

R,R Costarum ossa hic quoq; ubique ex parte nuda ostendunt.

S,S Costarum cartilagines.

T,T Intercostalium musculorum exteriorum inter ossa costarum fidem obscurorum imago.

V,V Interiorum musculorum exteriorum in canalignorum arcuum costarum interualla consimilium forma.

X Primus scapulam mouentium, a, b, c circumscriptus.

Y Secundi thoracem mouentium portio.

Z Recti abdominis musculi portio.

& Obliqui forsum sua fibras ex porrigens abdominis musculus, a, b, c circumscriptus.

b Vbilicus pars.

i Tellis intimus ipsum musculum obtectus.

k Venæ arteriæ seminalium antequam testi inseruntur ima pars.

l Vas seminis à teste deferens.

m Tellis musculus.

n Ligamentum abdominosa scapulæ processu ad humerum pertinens humerum.

o Interior scapulæ processus.

p Primum ligamentum humeri arcuatum proprium.

q Brachij os.

r Cubitum flectentium anterior, ex capita a & b nonnunquam tendinem r.

ss Cubitum flectentium posterius.

t Cubitum extendentium primi pars.

u Radium in pronationem ducentium primus.

x Radij in supinum motum autem primus.

y Portio tertij brachiale mouentium.

a Primus digitos manus mouentium a, b, c, d quatuor ipsum indicantes tendines.

ß Secundi digitos mouentium portio.

γ Vnæ portio.

δ Tertij digitos mouentium portio.

ε Pars vigesimiseptimi digitos mouentium, quæ tendinem insertis brevis ossi pollicem sustinent.

ζ,ζ Duæ portiones sunt alterius vigesimiseptimi muscularis partis, quæ sola tendinem pollicis insternit.

η,η Ligamentum transuersum in brachialis interna sede positum, hic digitum ostenditur.

ι Maioris digitum qui primum pollicis os flectitur.

κ,κ Tendines secundi digitos mouentium musculi.

λ Alterius musculus parui digiti primum os flectentium.

μ Ilium os hic extorsum ossi propter obliquè descendentem abdominis musculum inde reflectitur.

ν Secundi femur mouentium portio.

ξ Septimi femur mouentium portio.

ο Sexti femur mouentium portio.

π Noni tibiæ mouentis.

ρ Septimi tibiam mouentium portio.

σ Quinti femur mouentium portio, cui oculeus committitur.

τ Secundus tibiam mouentium, cuius insertionem a notat.

υ Octaui tibiam mouentium portio.

φ Quarti tibiam mouentium portio.

χ,χ Exiguum pisce ossis pars.

ψ Hic sextus pedem mouentium musculus à ilicæ osse oft reflectus.

ω Decimiquarti digitos mouentium, cuius aliquot tendines a, b insigniuntur.

τ Digitos mouentium decimiquinti.

α Nonus pedem mouentium.

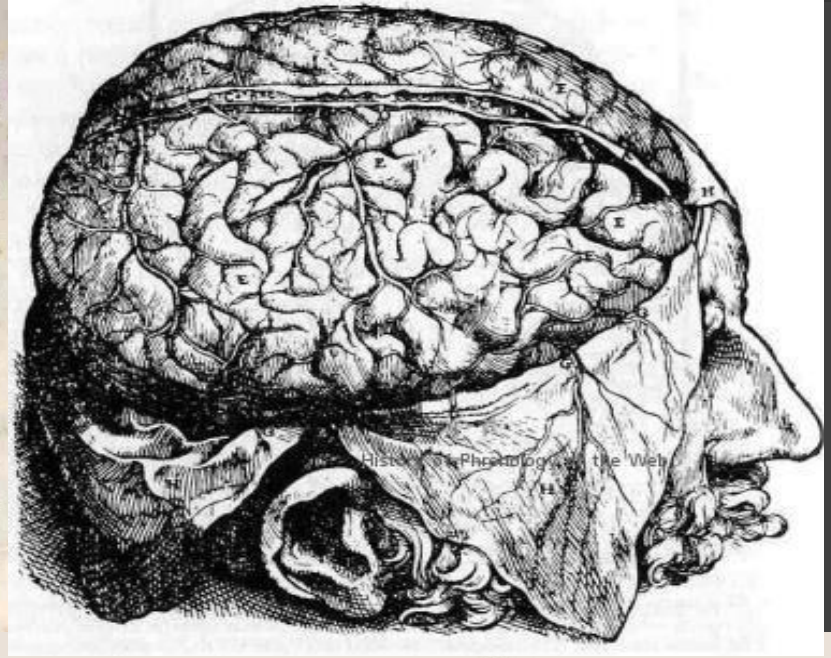
ω Sextus pedem mouentis. R. relqua in hoc cruce cum dextro conuenit.

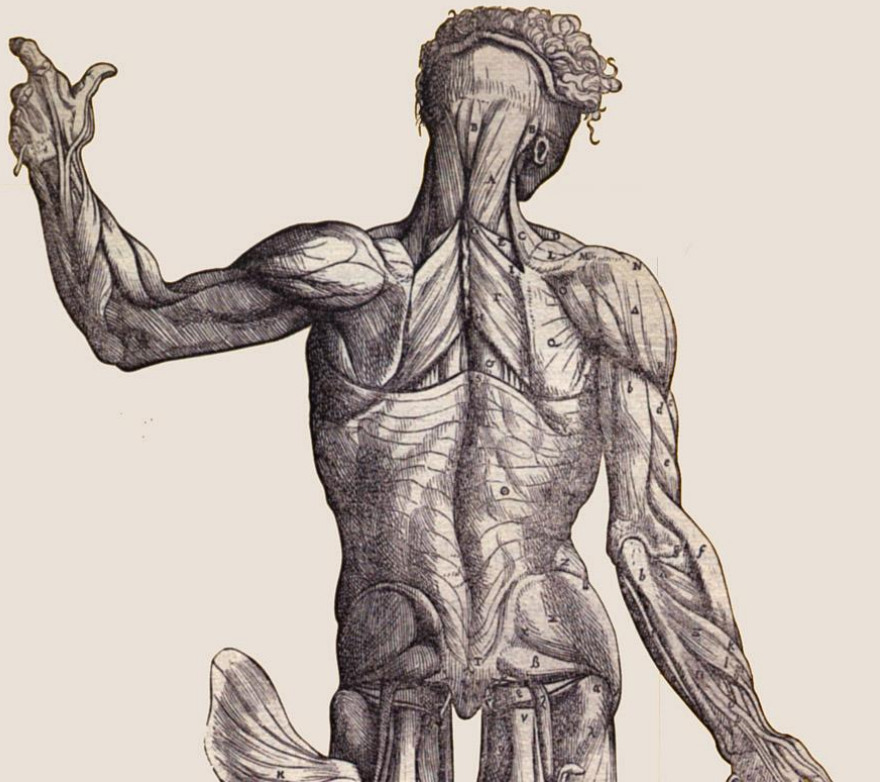
Δ Oculus simul cum ipsius musculis adhuc integris à sua sede ereatus, humi iacet.

Ξ Sex primi oculi musculi hic ab exortu ad insertionem usq; sunt liberati.

π Septimus in sua loco relictus, ex nervo inferne ortus in exteriorem oculi insignitur.

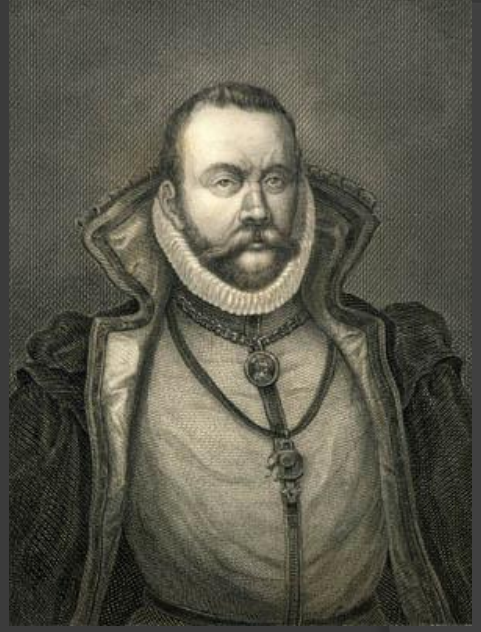
OMNIVM

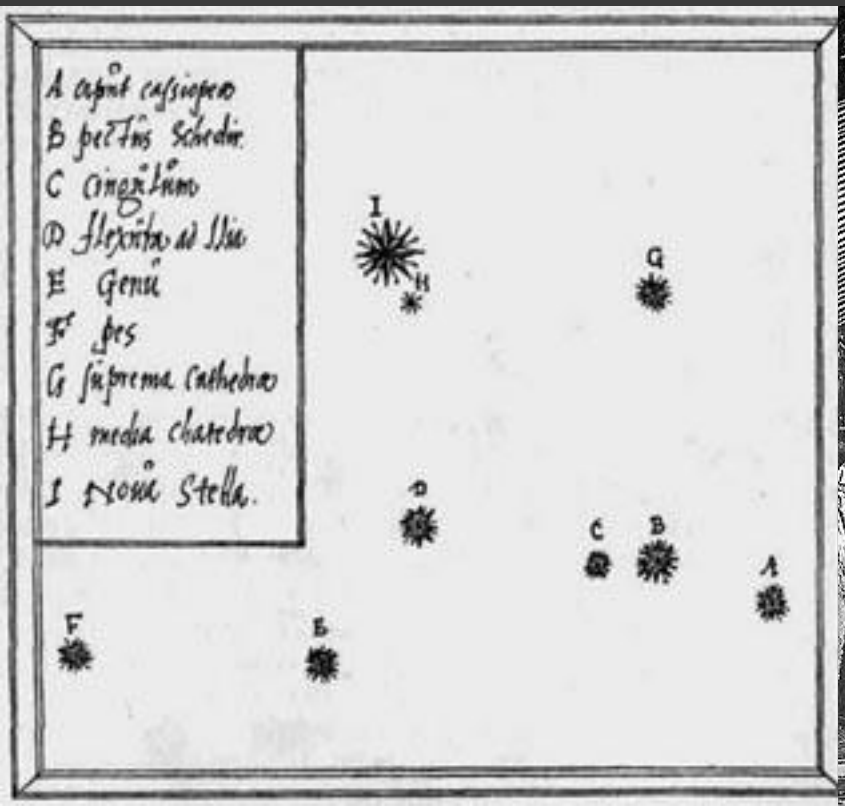




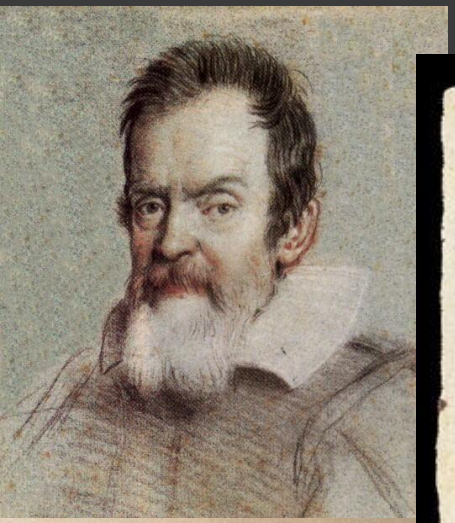
Tycho Brahe's observations of the new star of 1572 and *comet* of *1577*

He concluded that, unlike Aristotle's idea, the new star and the comet were in the celestial region.

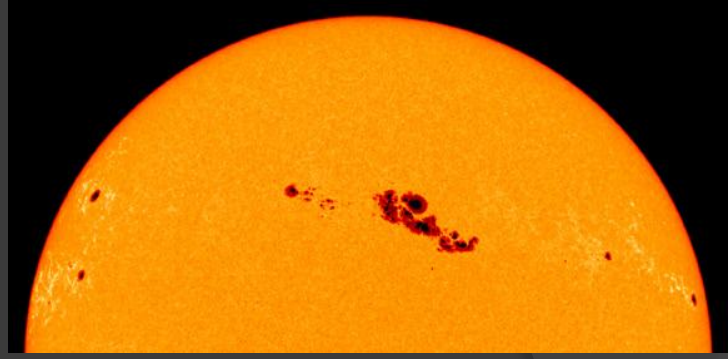




Galileo's Achievements

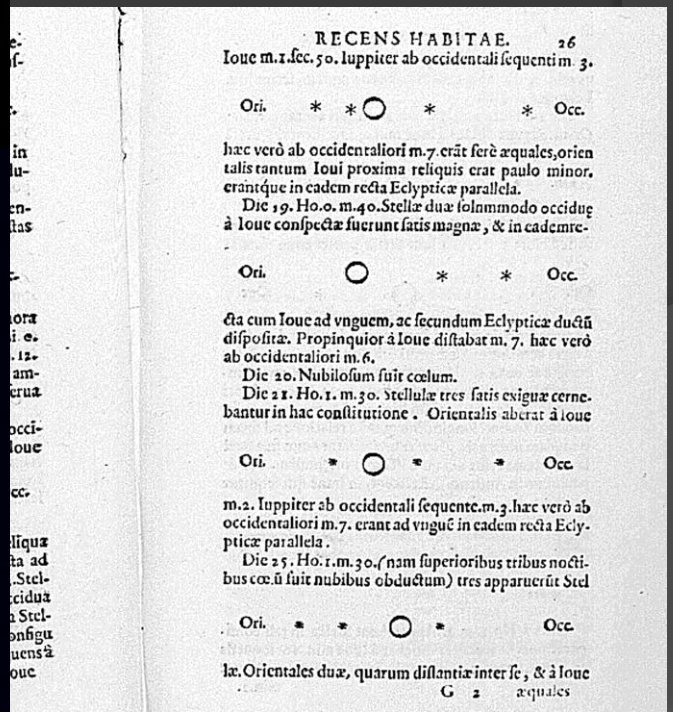


Moon's surface moon's surface consists of valleys, plains and mountains much like the surface of the Earth



Observation of sunspots

Discovery of moons around Jupiter



RECENS HABITAE. 26

Ioue m.1.ſec.50. Iuppiter ab occidentali ſequenti m. 3.

Ori. * * ○ * * Occ.

hæc verò ab occidentaliori m.7. erãt ferè æquales, orien talis tantum Ioui proxima reliquis erat paulo minor, erantque in eadem recta Eclypticæ parallela.

Die 19. Ho.0. m.40. Stellæ duæ ſolummodo occidue à Ioue conſpectæ fuerunt ſatis magnæ, & in eademre-

Ori. ○ * * Occ.

cta cum Ioue ad vnguem, ac ſecundum Eclypticæ ductũ diſpoſitæ. Propinquior à Ioue diſtabat m. 7. hæc verò ab occidentaliori m. 6.

Die 20. Nubiloſum fuit cœlum.

Die 21. Ho.1. m.30. Stellulæ tres ſatis exiguæ cerne-bantur in hac conſtitutione. Orientalis aberat à Ioue

Ori. * ○ * * Occ.

m.2. Iuppiter ab occidentali ſequente m.3. hæc verò ab occidentaliori m.7. erant ad vnguẽ in eadem recta Ecly-pticæ parallela.

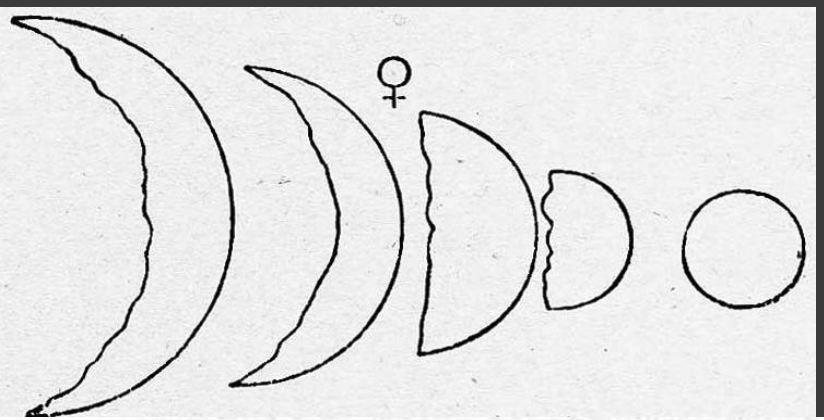
Die 25. Ho.1. m.30. (nam ſuperioribus tribus noctibus cœlũ fuit nubibus obductum) tres apparuerũt Stel

Ori. * * ○ * Occ.

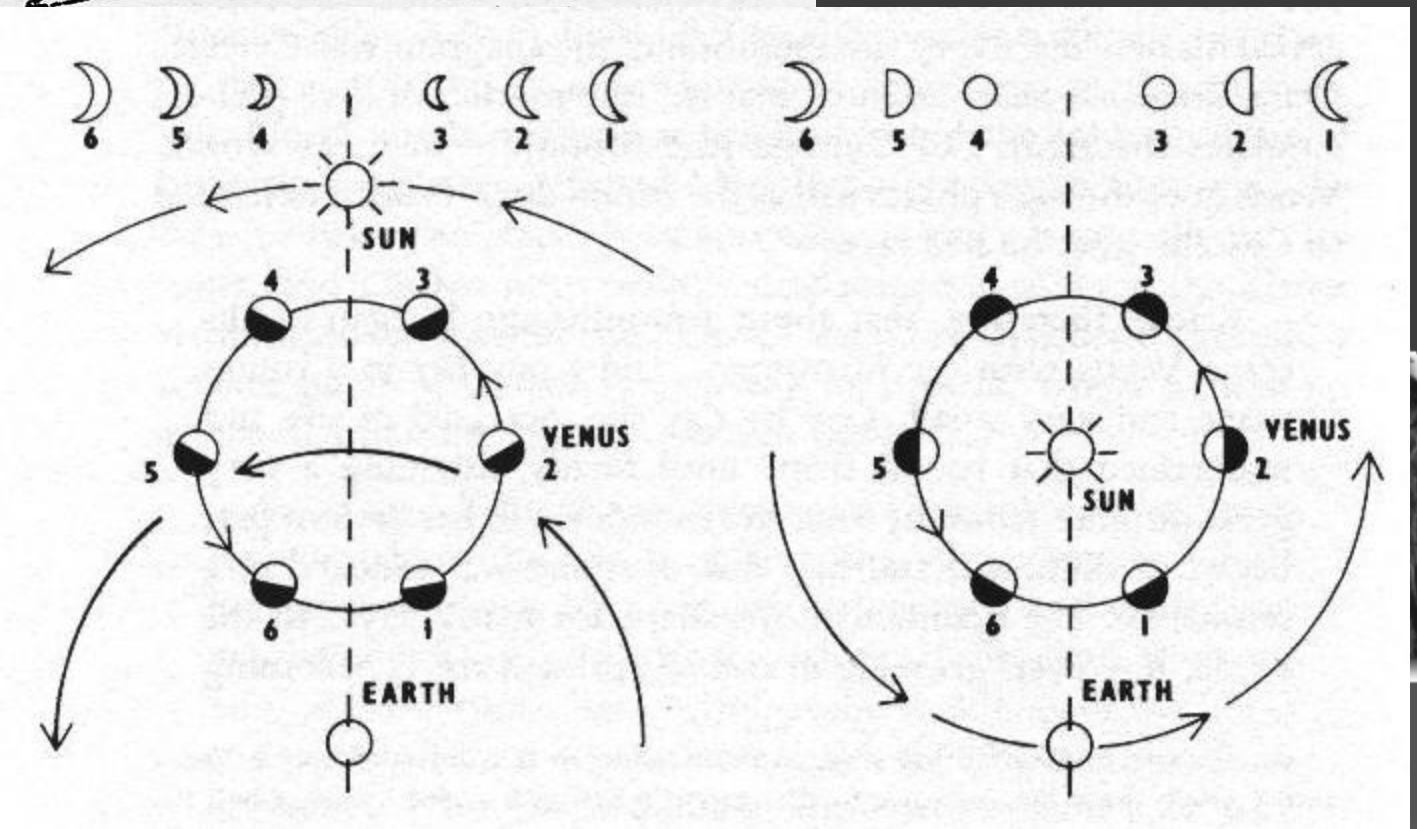
læ. Orientales duæ, quarum diſtantiæ inter ſe, & à Ioue

G 2 æquales

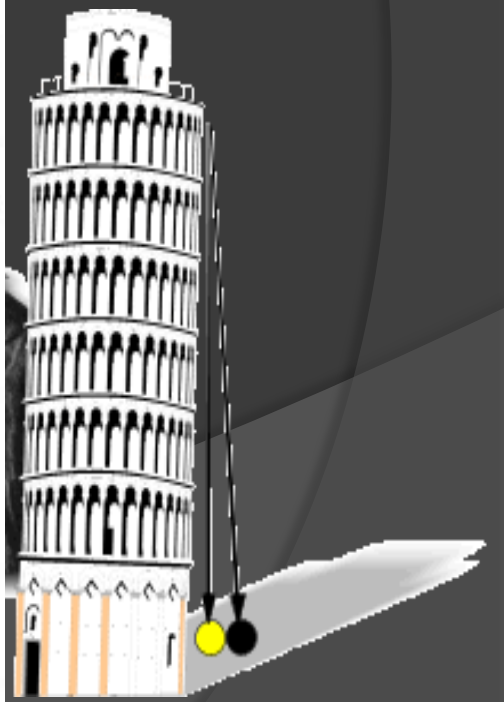
Galileo's Achievements



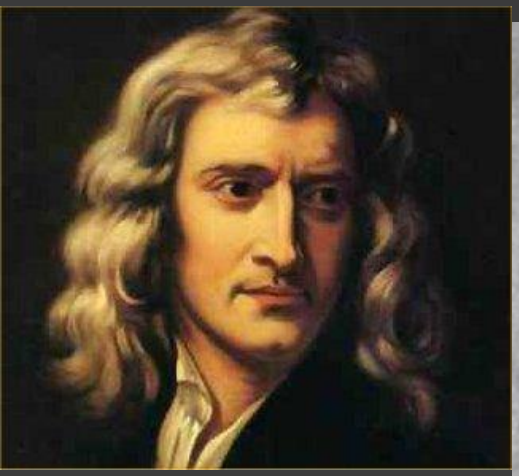
Galileo observed the phases of Venus

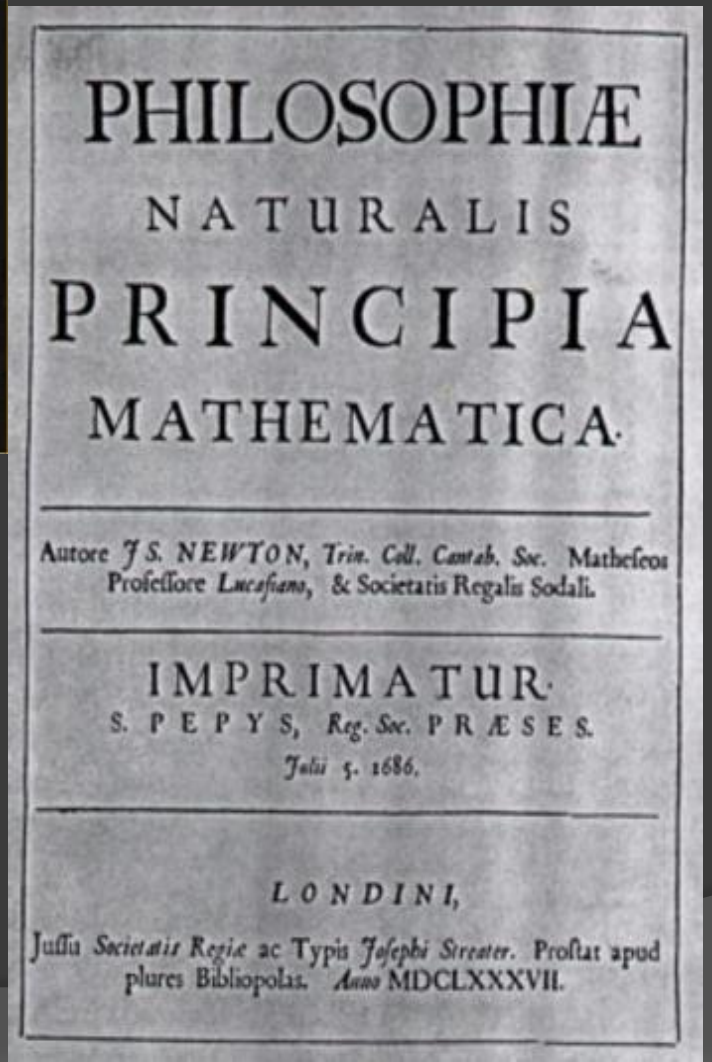


Heavy objects do not fall faster than lighter ones



- **Isaac Newton (**1642-1727) **and the and the Culture of Newtonianism**
- Newton: The first mathematical physicist



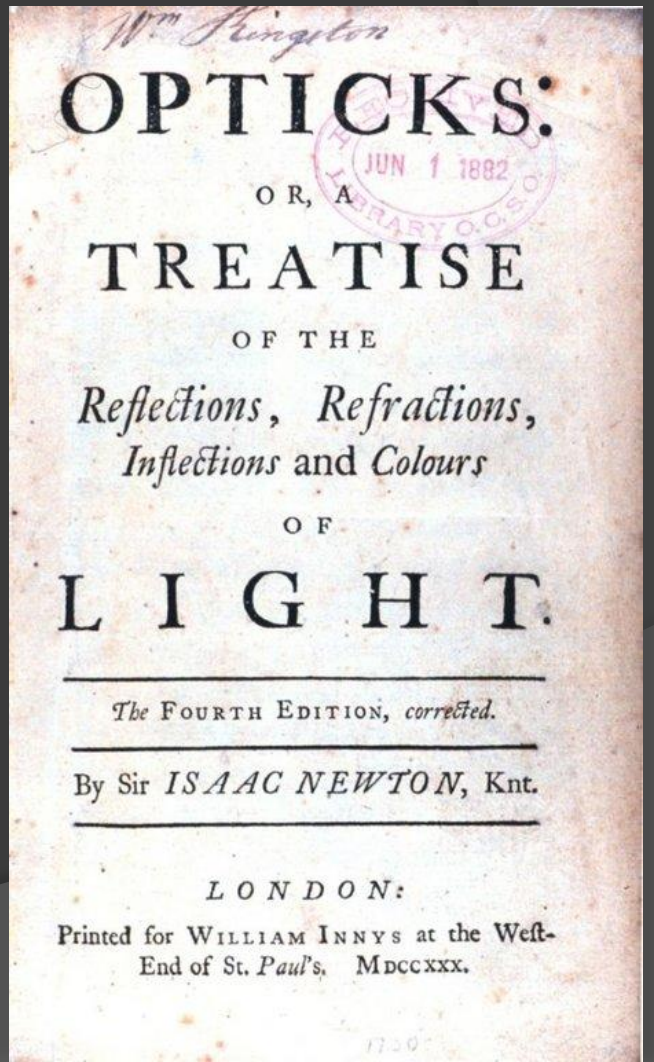


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

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

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

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



OPTICKS:
OR, A
TREATISE
OF THE
Reflections, Refractions, Inflections and *Colours*
OF
LIGHT.

The FOURTH EDITION, *corrected.*

By Sir *ISAAC NEWTON*, Knt.

LONDON:
Printed for WILLIAM INNYS at the West-End of St. *Paul's*. MDCCXXX.

- Newton showed that the motions of objects on Earth and of celestial bodies are governed by the same set of natural laws

- In optics, he developed a theory of color based on the experiment that a prism separates white light into the many colors that form the visible spectrum. He also built the first reflecting telescope.

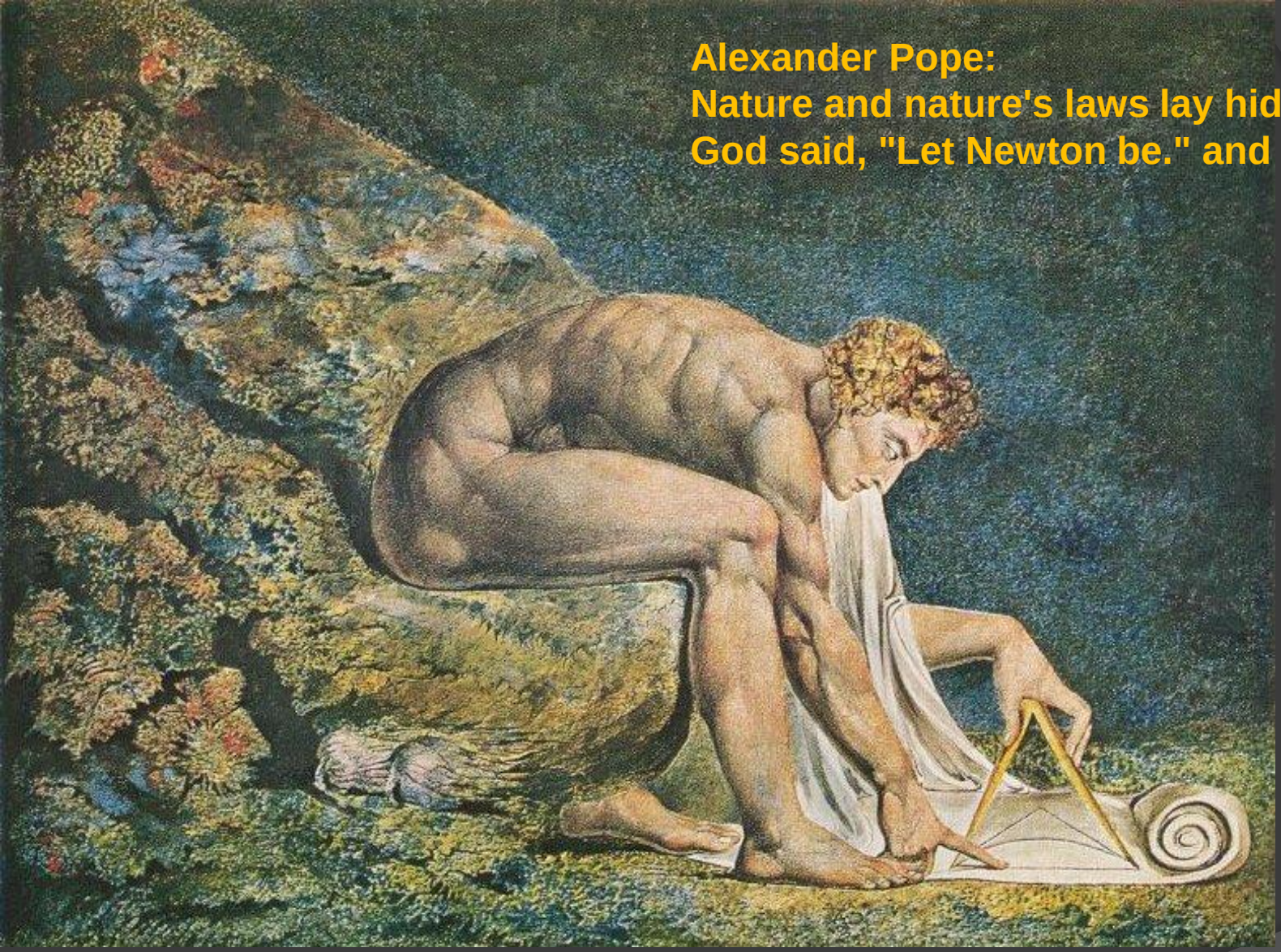
- In mathematics, Newton shared the credit with Gottfried Leibniz for the development of the differential and integral calculus.

- In the *Principia*, Newton described universal gravitation and the three laws of motion

- **I. Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.**

- **II. The relationship between an object's mass *m*, its acceleration a, and the applied force *F* is *F* = *ma*.**

- **III. For every action there is an equal and opposite reaction.**



"Newton“ (1795), by William Blake; here, Newton is depicted as a "divine geometer".

- Natural laws
- Mathematization of nature
- Experimental philosophy
- Scientific approach in utilizing natural resources
- Employment of science in technology