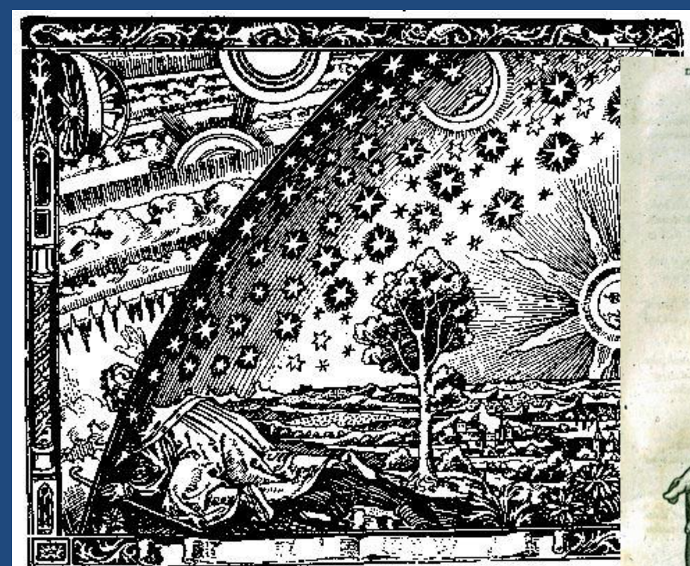
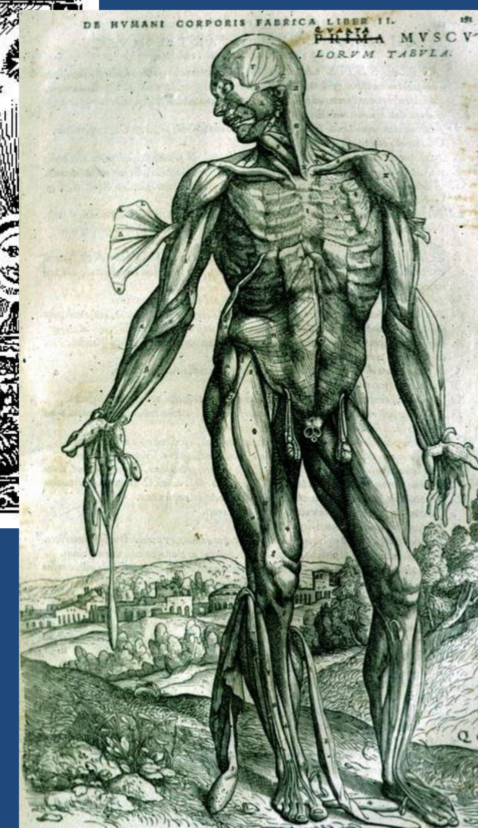
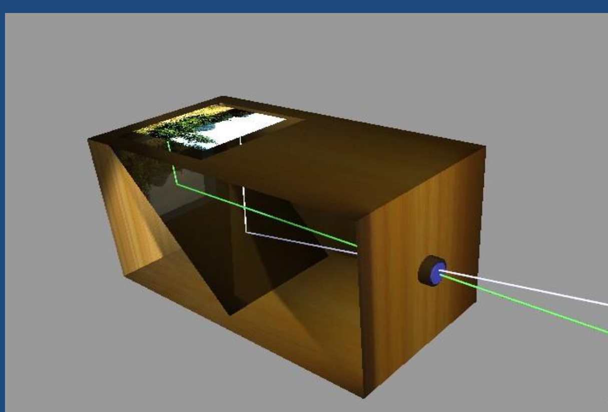
The Huntington

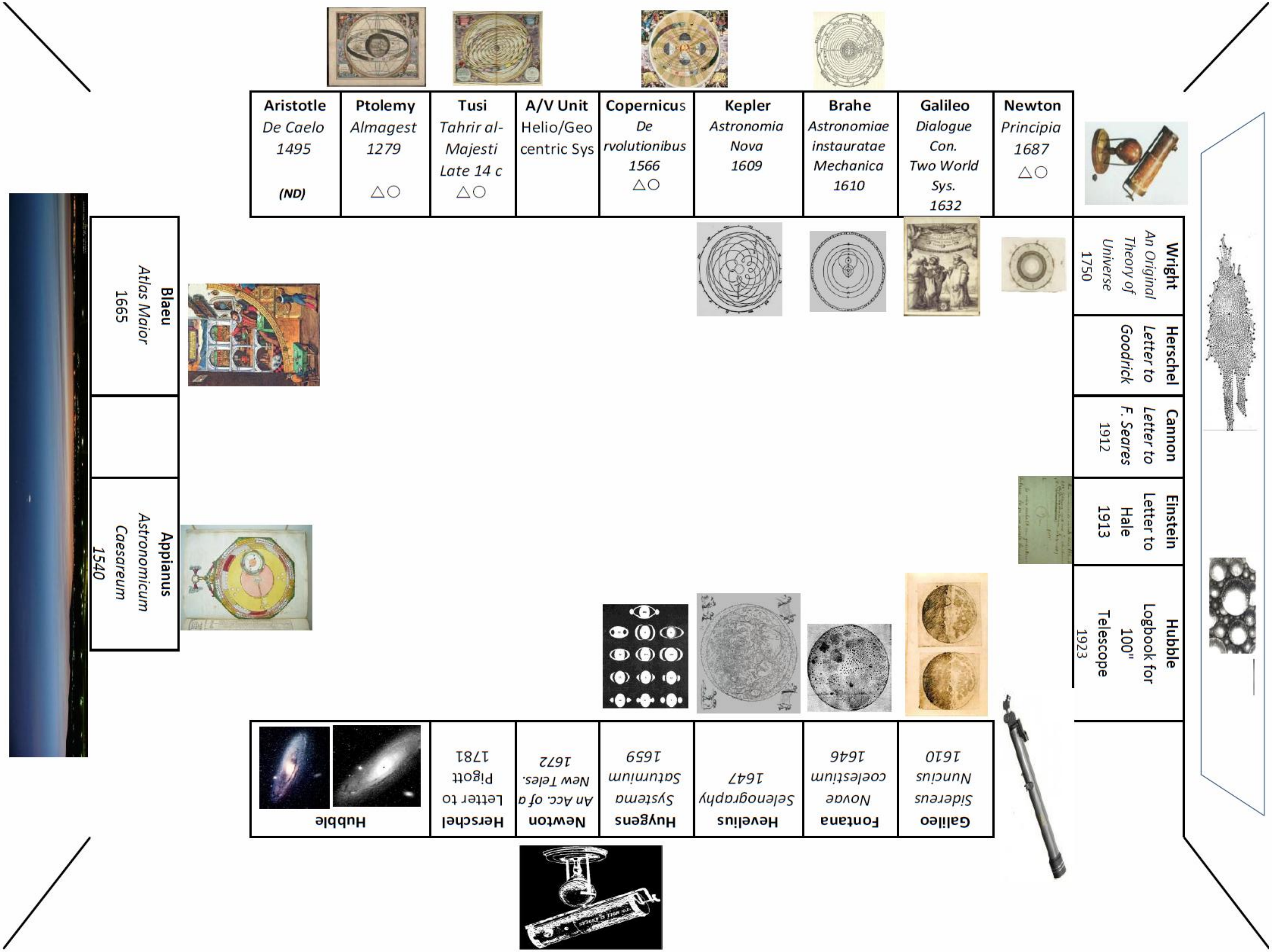
Library, Art Collections, and Botanical Gardens

History of Science School Program








Aristotle
De Caelo
1495
(ND)
Ptolemy
Almagest
1279
△○
Tusi
Tahrir al-Majesti
Late 14 c
△○
A/V Unit
Helio/Geo centric Sys
Copernicus
De rvolutionibus
1566
△○
Kepler
Astronomia Nova
1609
Brahe
Astronomiae instauratae Mechanica
1610
Galileo
Dialogue Con. Two World Sys.
1632
Newton
Principia
1687
△○
Wright
An Original Theory of Universe
1750
Herschel
Letter to Goodrick
Cannon
Letter to F. Seares
1912
Einstein
Letter to Hale
1913
Hubble
Logbook for 100" Telescope
1923
Galileo
Sidereus Nuncius
1610
Fontana
Novae coelestium
1646
Hevelius
Selenography
1647
Huygens
Systema Saturnium
1659
Newton
An Acc. of a New Teles.
1672
Herschel
Letter to Pigott
1781
Hubble
Blaeu
Atlas Maior
1665
Appianus
Astronomicum Caesareum
1540

Aristotle	Pliny the Elder	Dioscorides	Gesner	Topsell	Topsell
De anima..	*Naturalis*	*Materia*	*Historiae*	*Fowles of*	*History of*
1498	*Historia*	*Medica*	*animalium*	*Heaves*	*Four footed..*
ND	*1469*	*1549*	*1551-87*	1613	1658

Robert Hooke
Micrographia
1665

Leeuwenhoek
Werken
1684-1718

Maria Merian
Metamorphosis
1730

A/V

Catesby
Natural His. of Carolina
1743

Watson & Crick
Molecular Structure of the Nucleic Acid
1953

Bateson
Mendel's Principles
1909

Mendel
Versuche.
1865-66

Darwin
et al
Zoology of HMS Beagle

Darwin Wallace
On the Tendency.1858

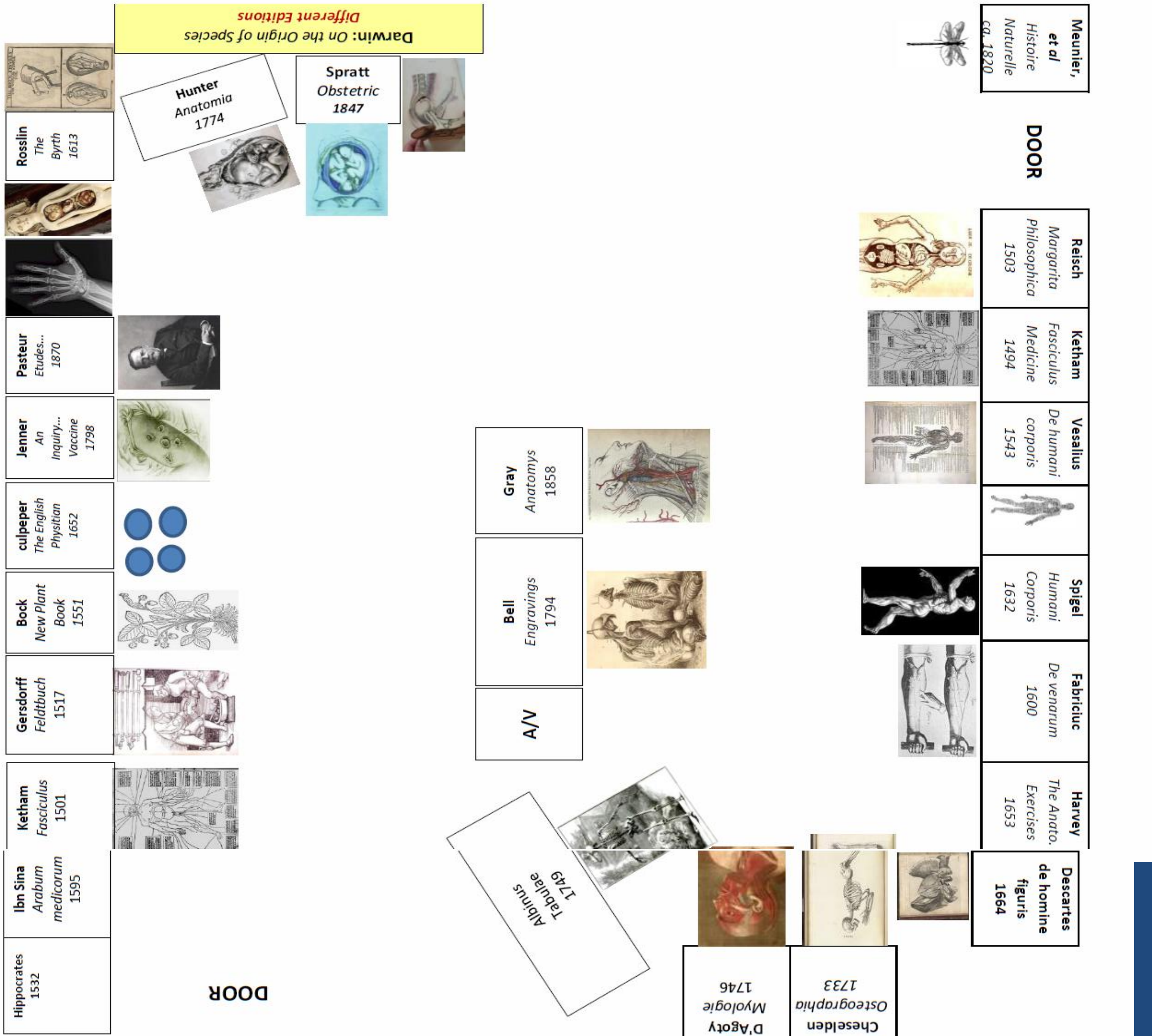
Darwin
Geological influence

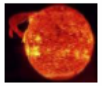
Cuvier
Recher. sur les Fossiles
1812

Lamarck
System des animaux
1801

Cuvier Lamarck Books

Aristotle
De anima..
1275


Darwin: On the Origin of Species
Different Editions
Meunier, et al
Histoire Naturelle
ca. 1820
DOOR
Reisch
Margarita Philosophica
1503
Ketham
Fasciculus Medicine
1494
Vesalius
De humani corporis
1543
Spigel
Humani Corporis
1632
Fabriciuc
De venarum
1600
Harvey
The Anato. Exercises
1653
Descartes
de homine figuris
1664
Cheselden
Osteographia
1733
D'Agoty
Myologie
1746
Albinus
Tabulae
1749
A/V
Bell
Engravings
1794
Gray
Anatomys
1858
Hunter
Anatomia
1774
Spratt
Obstetric
1847
Rosslin
The Byrth
1613
Pasteur
Etudes...
1870
Jenner
An Inquiry... Vaccine
1798
culpeper
The English Physitian
1652
Bock
New Plant Book
1551
Gersdorff
Feldtbuch
1517
Ketham
Fasciculus
1501
Ibn Sina
Arabum medicorum
1595
Hippocrates
1532
DOOR



Plato *Timaeus*

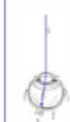
Euclid *Optica*

Alhacen *Kitab al-Manazir*

Kepler *Ad Vitellionem*

Descartes *Discourse*

Kircher *Ars Magna*



Kircher Mirroe

Boyle *Expr. & cons. …colours* 1669

Grimaldi *Physico mathesis de lumine* 1665

Newton New Theory about Light &Colors 1671/2

Prism Expr.

Newton *Opticks* 1717

A. Werner *Colours* 1814

R. Ridgway *Color Stand.* 1912

B. Franklin *Expr. Obsr. Electricity* 1754-60

van Marum *Eerste vervolg* 1787

Volta Latest Attm. Galvani

Faraday *Expr. Resch Electricity* 1846

Edison's *Guide Incond. Lamps*

Tesla Letter to A. Adams

Fraunhofer Sun's Spectrum

Kirchhof Spectrum

Lockyer *Stud. In Spectrum*

Maxwell *A dyna. theory of the electromagn field 1864*

Einstein *Zur Elektrodynamik bewegter Körper 1905*

First Civilizations

- These civilizations were based on irrigation agriculture

- All Mesopotamian civilizations developed centralized political authorities and complex bureaucracies to collect, store, and redistribute agricultural surpluses
- All are characterized by monumental buildings, brick temple complexes, and pyramids known as ziggurats.

- Mesopotamian civilizations developed writing, mathematics, and astronomy.

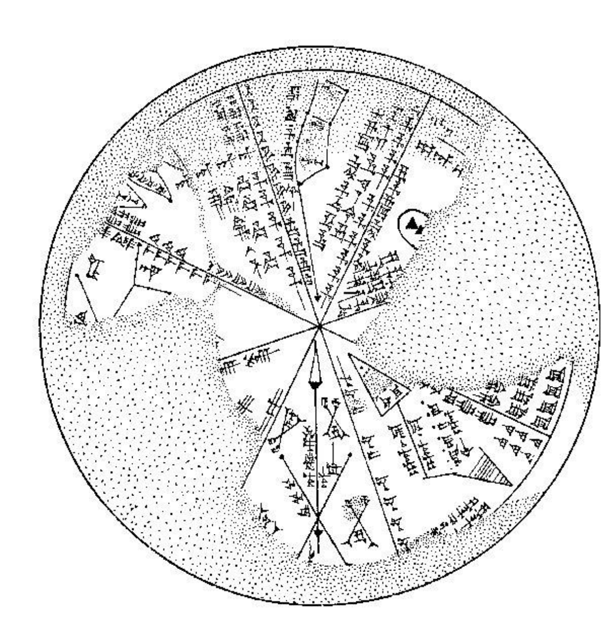
Mesopotamian Astronomy

- Measuring the length of daylight by water clock, gnomon, etc.
- Recording the position of stars, and making catalogues of stars and constellations
- Recording the helical rising and setting of planets, and providing schemes to predict the rising and setting of planets
- Recognizing that astronomical phenomena are periodic , and applying mathematics to make predictions
- Developing a coordinate system to record the position of stars planets, and celestial phenomena like eclipses
- Recording the lunar and solar eclipses
- Observing and recording the first appearance of the new moon to establish a reliable calendar
- Dividing a circle into 360 degrees, a degree to 60 seconds, and a day to 24 hours

Venus tablet, 7th century BC
records the rise times of Venus and its first and last visibility on the horizon before or after sunrise and sunset in the form of lunar dates

Although Mesopotamian astronomy was sophisticated, it was empirical. The predictive Mesopotamian astronomy was arithmetical and did not involve cosmology, geometrical planetary models, and a philosophy to describe the physical world.

Egyptian astronomy, which was influenced by the Mesopoatmian astronomy, was also empirical.



Assyrian star map from Nineveh (K 8538). Counterclockwise from bottom: Sirius (Arrow), Pegasus + Andromeda (Field + Plough), [Aries], the Pleiades, Gemini, Hydra + Corvus + Virgo, Libra, Babylonian Cosmology

Shu, the god of the air, upholds Nut, the sky-goddess, while Geb, the earth-god, reclines under Nut.

Greek and Hellenistic Science

- **First Ionian /Greek philosophers**

Thales/Anaximander/

Anaximenes/Pythagoras/Parmenides/Heraclitus/

Empedocles/Anaxagoras/Democritus/Leucippus :

Speculation about nature, investigation of the fundamental nature of what exists, and questions about “the essence of things”

Although Greek science was highly infleuenced by the Egyptians and Mesopotamians, the Greeks were the first to look for general principles beyond observations

Thales (late 7^{th} to mid-6^{th} c. BC) : Water is the source of all things

Anaximander of Miletus (6^{th} c. BC) : *Apeiron* is the source of all things (*apeiron* means unlimited, indeterminate, or infinite)

Anaximenes of Miletus (early 6^{th} – late 6^{th} BC): *aer* (misty air) is the source of all things

Pythagoras of Samos (c. 570 – c. 500 BC): Numbers were the ultimate reality

Heracleitus of Ephesus (c.540 – c.480 BC): What is change?

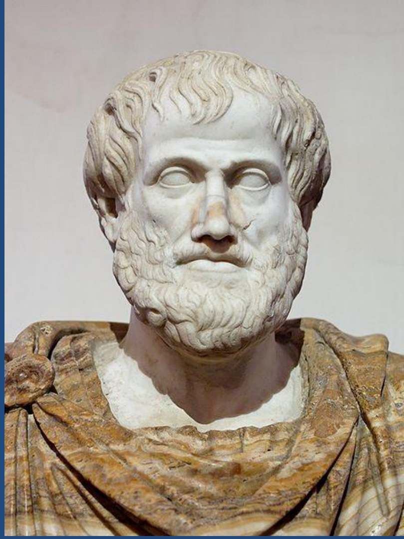
Parmenides of Elea (c.515 – mid-5^{th} c. BC): The earliest surviving example of deductive reasoning in ancient Greek appears in Parmenides' writing

Empedocles of Acragas (c.492 – c.432 BC): First philosopher to suggest that there are exactly 4 fundamental and eternal elements: air, earth, fire, water

Democritus of Abdera (c.460 – c.360 BC): Tiny uncuttable particles (*atoms*) which all are uniform material, and move through empty space, make whatever we see in the world.

Epicurus (late 4^{th} c. BC): Developed Democritus' idea which survived into early modern times

Aristotle (384 BC – 322 BC)



A student of Plato and teacher of Alexander the Great.

- Established a comprehensive system of philosophy

- Established a coherent theory of the cosmos wherein the categorized objects of the universe are arranged in a distinct configuration.

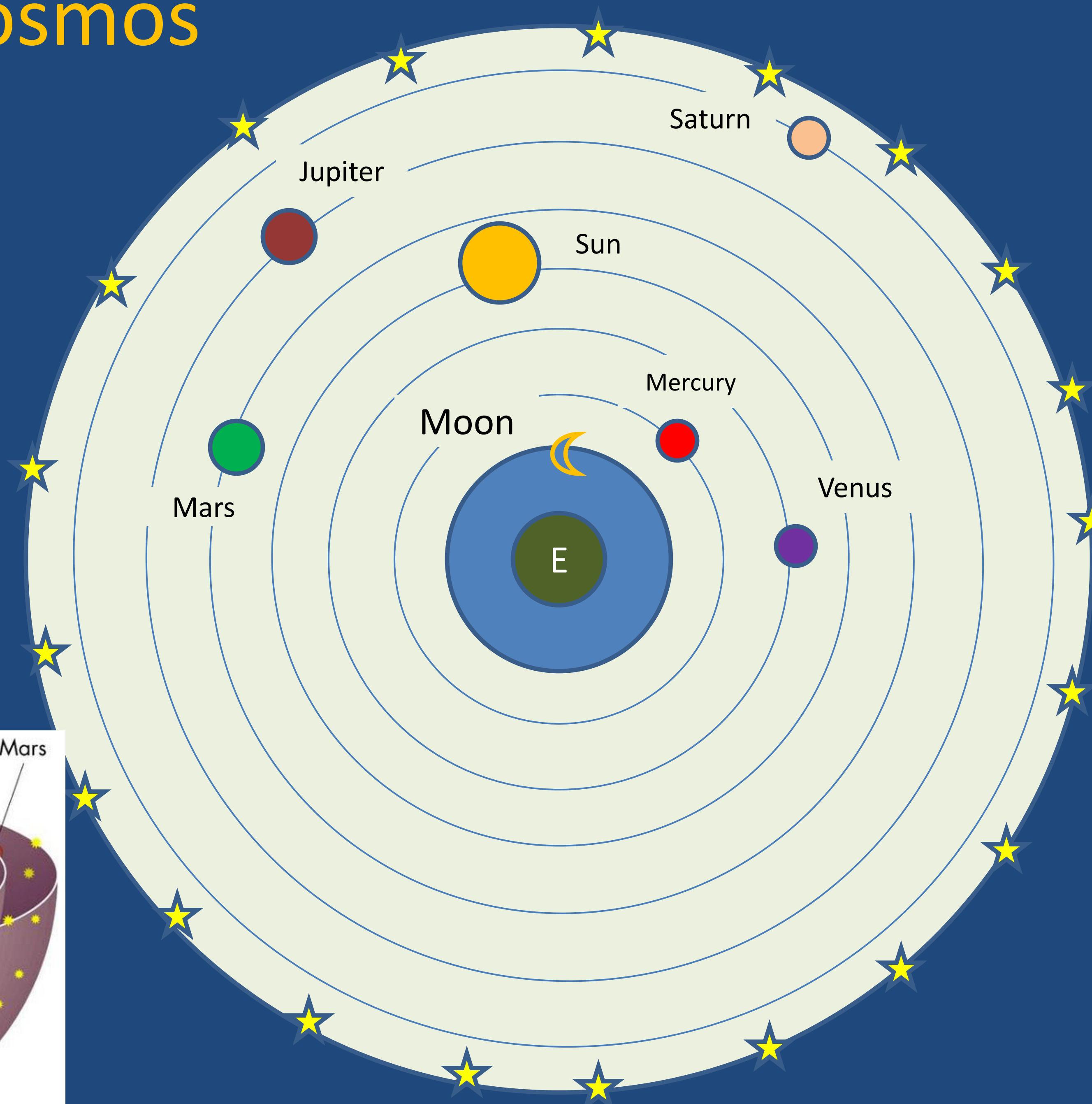
- Wrote systematically about physics, metaphysics, poetry, zoology, music, logic, ethics, politics, rhetoric, government, and even theater.

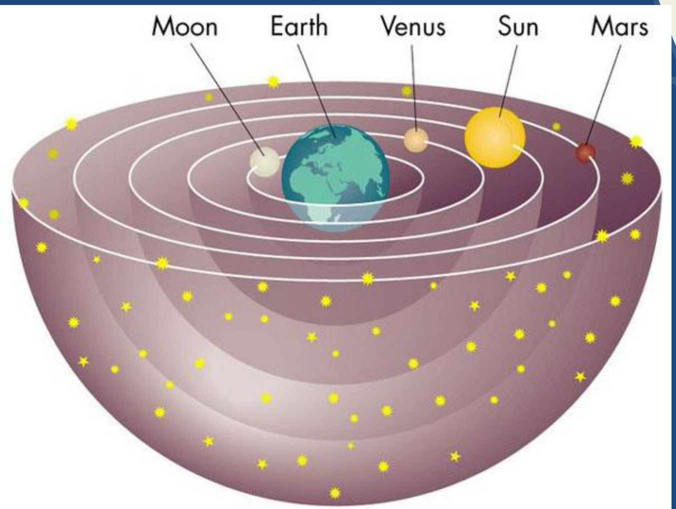
Aristotle's philosophy, and his views on physical sciences shaped medieval scholarship. His influence extended into 16th century.

Aristotle, *Physics,* Book 1, part 2

- The principles in question must be either (a) one or (b) more than one. If (a) one, it must be either (i) motionless, as Parmenides and Melissus assert, or (ii) in motion, as the physicists hold, some declaring air to be the first principle, others water. If (b) more than one, then either (i) a finite or (ii) an infinite plurality. If (i) finite (but more than one), then either two or three or four or some other number. If (ii) infinite, then either as Democritus believed one in kind, but differing in shape or form; or different in kind and even contrary.
- A similar inquiry is made by those who inquire into the number of existents: for they inquire whether the ultimate constituents of existing things are one or many, and if many, whether a finite or an infinite plurality. So they too are inquiring whether the principle or element is one or many.
- Now to investigate whether Being is one and motionless is not a contribution to the science of Nature. For just as the geometer has nothing more to say to one who denies the principles of his science-this being a question for a different science or for or common to all-so a man investigating principles cannot argue with one who denies their existence. For if Being is just one, and one in the way mentioned, there is a principle no longer, since a principle must be the principle of some thing or things.

Aristotle's cosmos





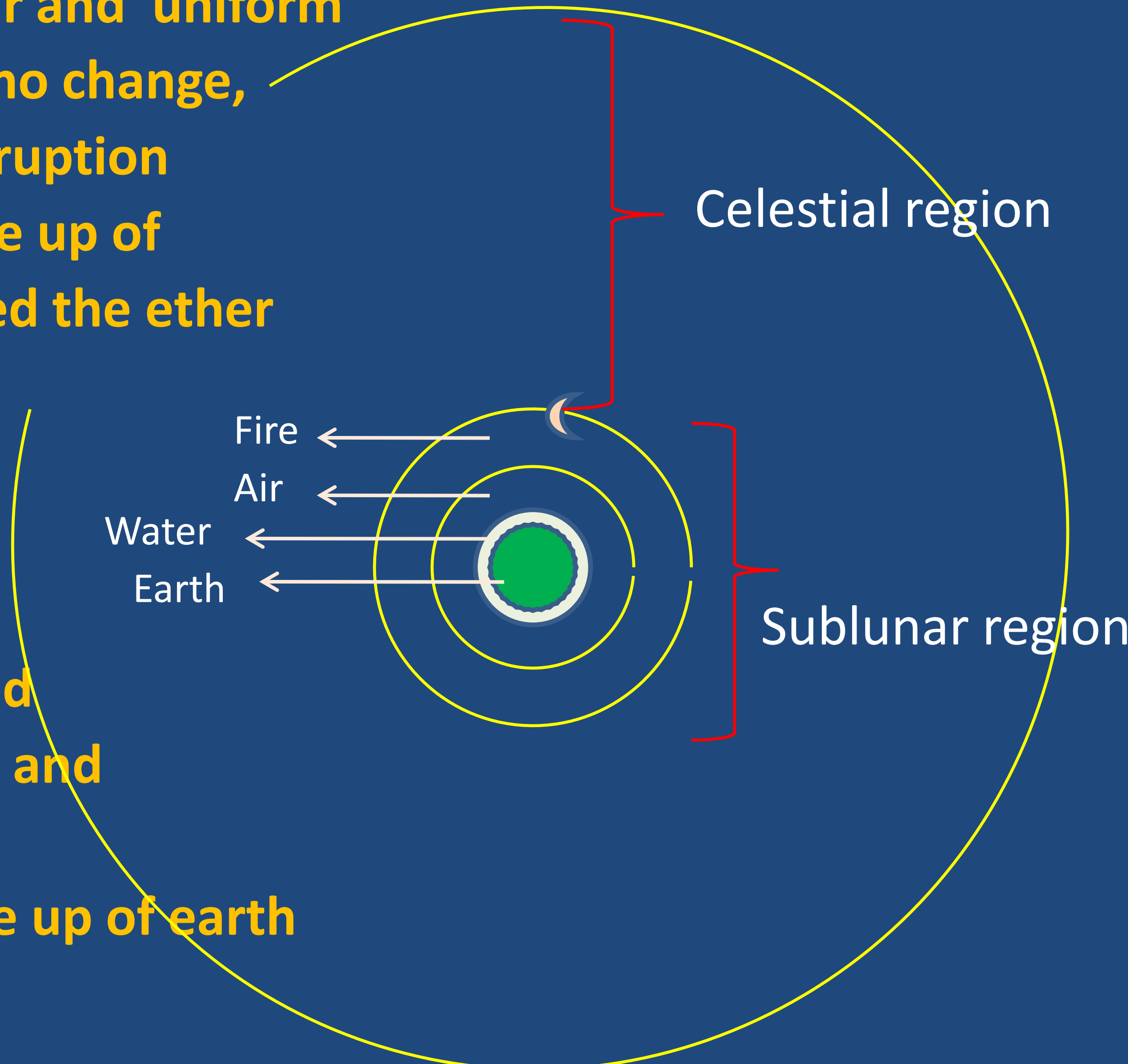
Celestial Region:

- **All motions are circular and uniform**
- **Everything is perfect, no change, no generation, no corruption**
- **Celestial region is made up of the fifth element called the ether**

Sublunar Region:

- **Motions are either upward or downward**
- **Everything is subjected to change, generation and corruption**

Sublunar region is made up of earth water, air, and fire

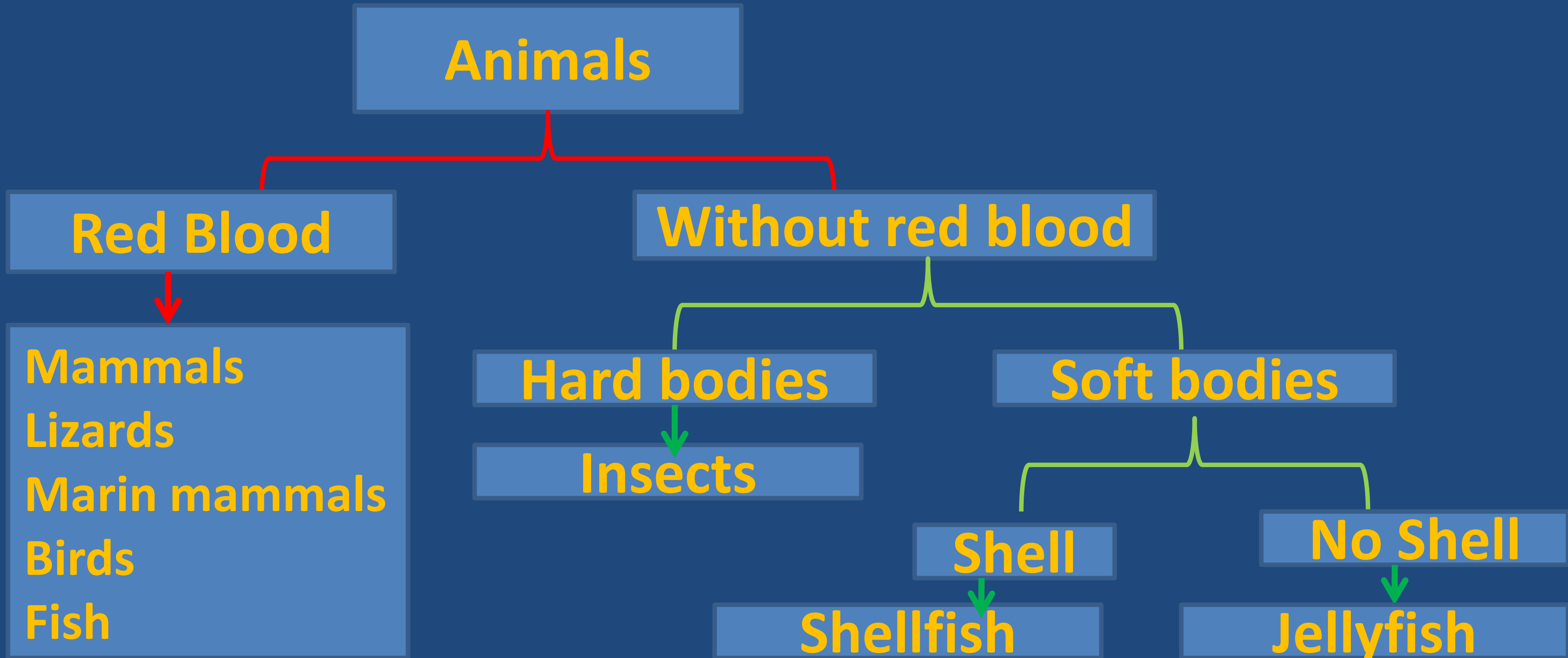


Two distinct regions, different substances, different kind of motions, TWO DIFFERENT PHYSICS

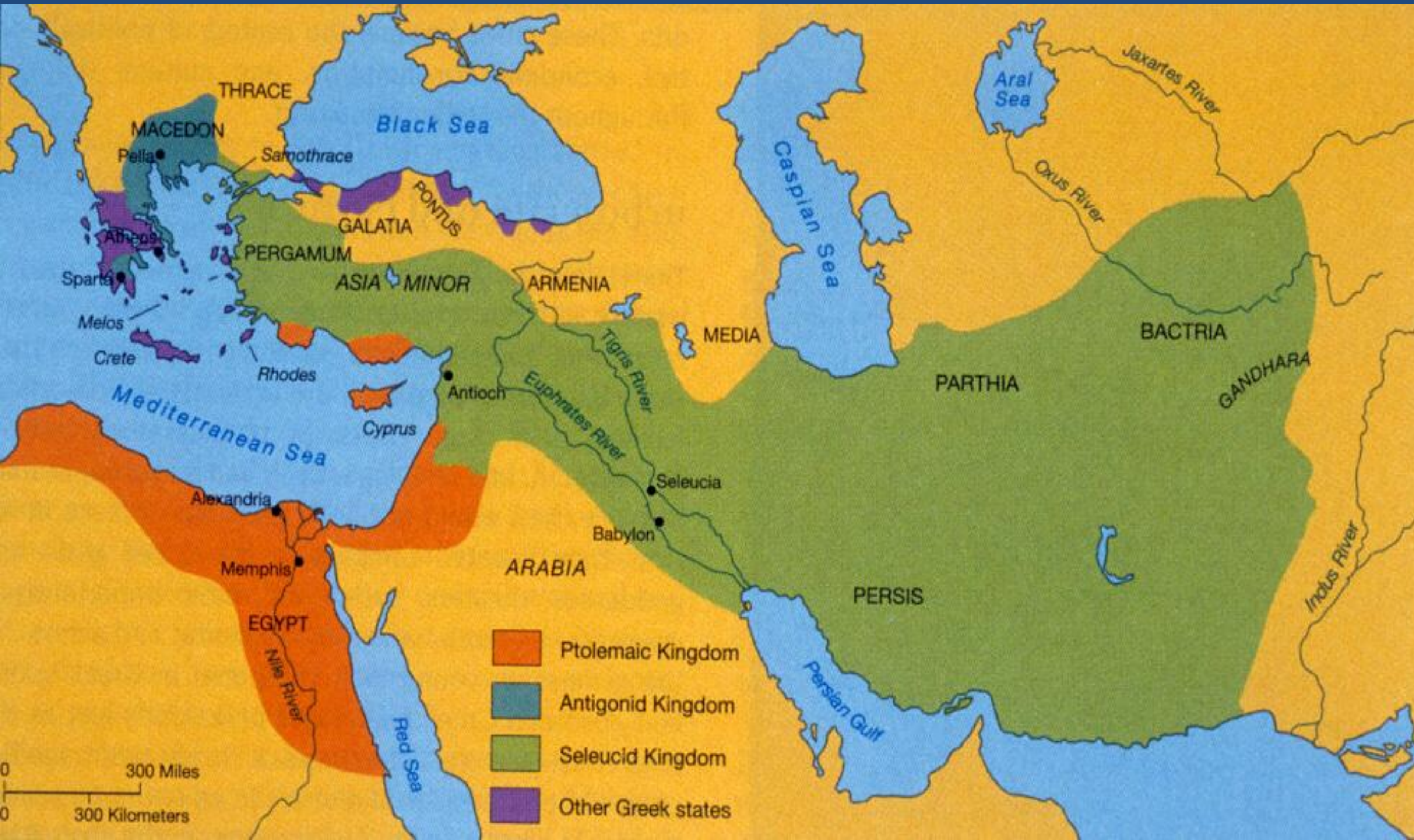
Aristotle and the life sciences

- Aristotle was originally a zoologist. He is considered the father of the life sciences.

- Aristotle grouped together animals with similar characters into **genera** (in a much broader sense than we use now) and then characterized the **species** within the genera.



The Hellenistic Period



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

1. The greater 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

- 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 Astronomy / Celestial Anomalies

Though the heavenly bodies are performing uniform circular motions, astronomical observations shows some "irregular" motions in planets: Mars, Jupiter, and Saturn, for example, periodically slow up in their overall course from west to east through the stars, and double back away before continuing in their original direction. This doubling-back is called retrograde motion.

Also, the length of the seasons are not equal. It means that either the earth is not at the center of the sun's sphere, or the sun has anomaly.

Aristotle and his contemporaries knew about those anomalies, but the problem was how to explain the anomalies based on uniform circular motion of the planets.

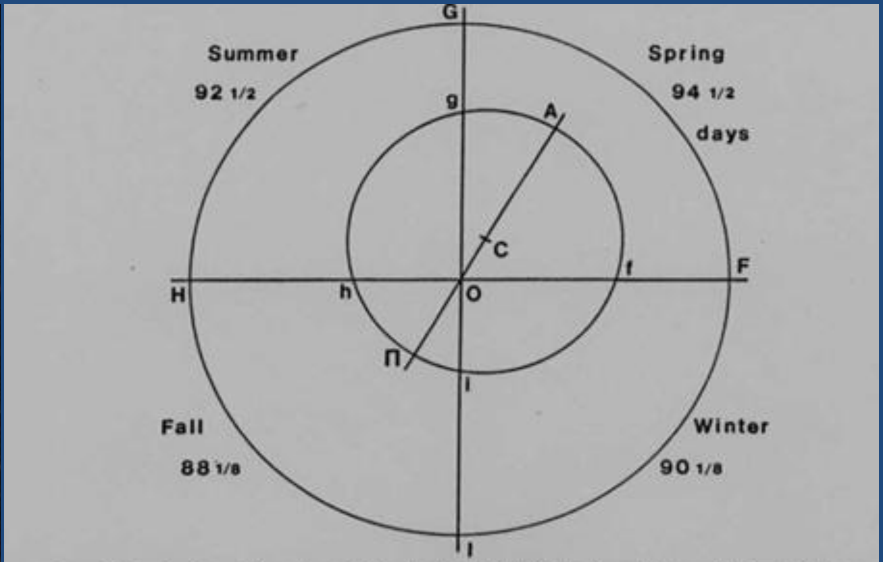
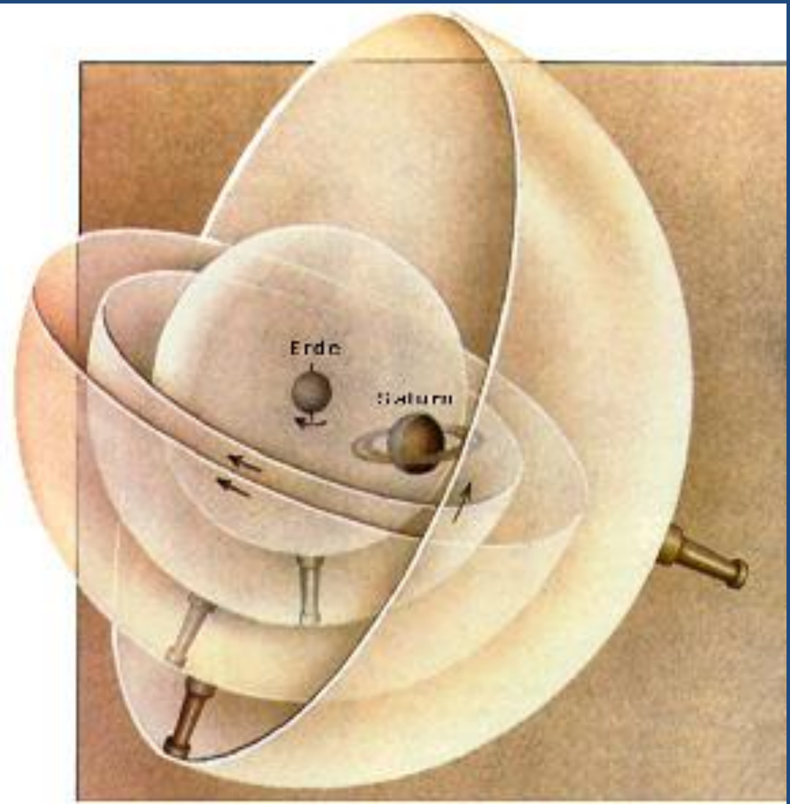
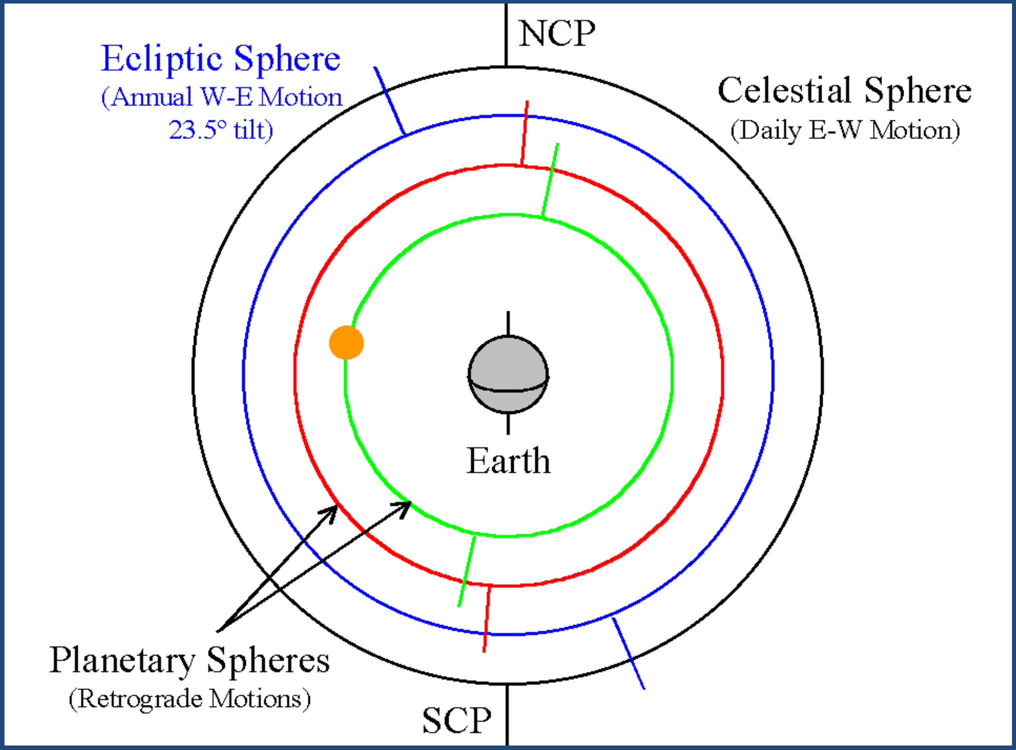
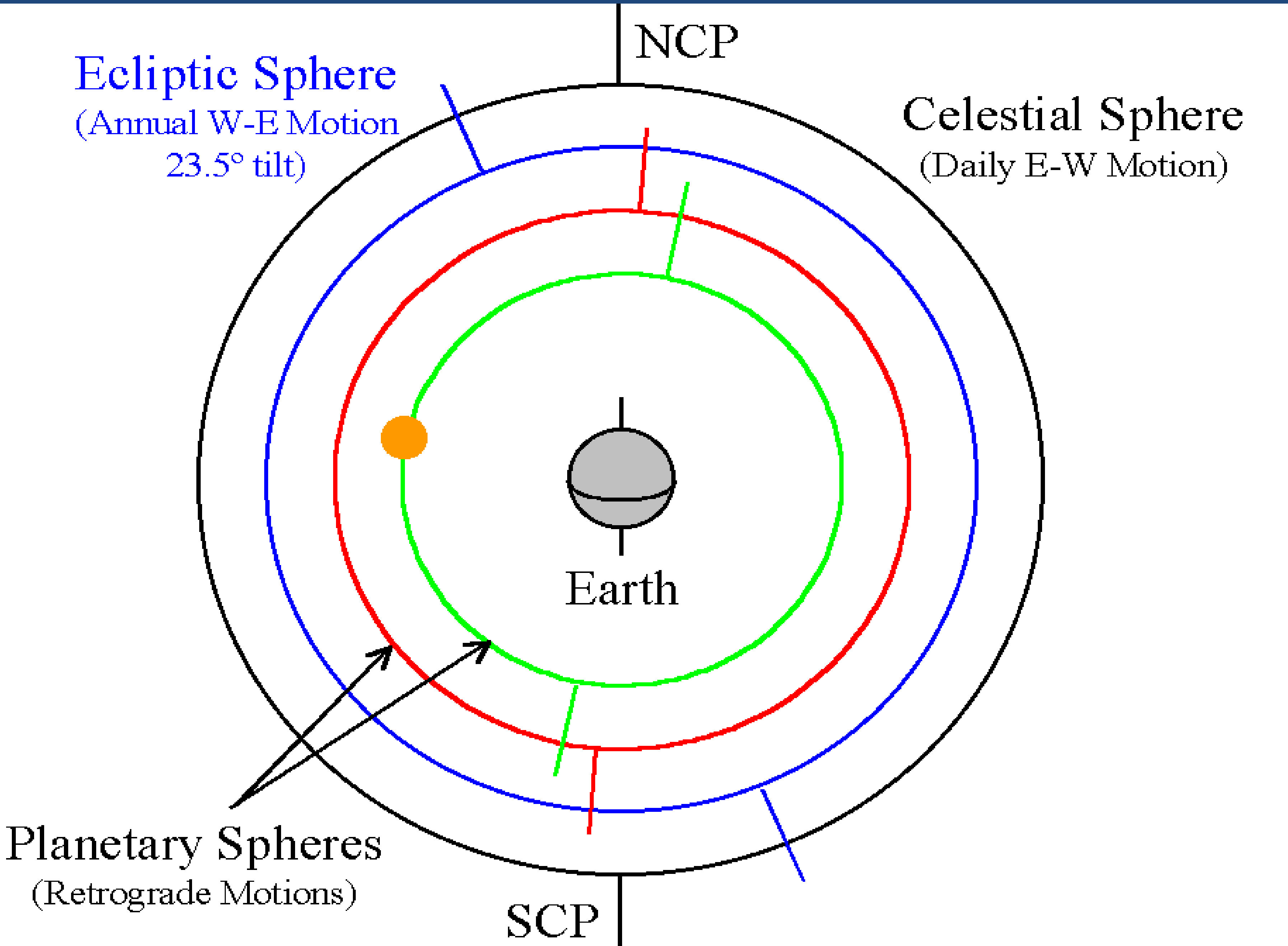


Figure 1. *The solar theory of Hipparchus and Ptolemy. (In this and all the following figures, the plane of the figure is the plane of the ecliptic, as viewed from above its north pole.) The earth is at* O, *which is the center of the sphere of stars, represented by circle* FGHI. *The sun travels at constant speed on its eccentric circle* fghi, *the center of which is at* C. A *is the apogee of the sun's eccentric circle, and* π *is the perigee.*

Eudoxos of Knidos (early fourth century B.C.) and his student Callippus proposed a concentric model, in which the revolution of spheres about different axes in different directions with different speeds produced the observed planetary phenomena. However, this model was not successful and was not accurate enough to predict the motion of planets.






NCP
Ecliptic Sphere
(Annual W-E Motion
23.5° tilt)
Celestial Sphere
(Daily E-W Motion)
Earth
Planetary Spheres
(Retrograde Motions)
SCP

Epicycle / Deferent Model

In the 2nd century AD, Claudius Ptolemy developed a planetary model, in which planets were revolving uniformly on a small orb – named epicycle- whose center was moving uniformly on a bigger circle, called deferent. A combination of deferent/epicycle, with different sizes, directions, and speeds produced the observed planetary phenomena. Ptolemy's book of mathematical astronomy – the *Almagest* - was the bible of astronomy before the introduction of modern astronomy in the 17th century. We will investigate Ptolemy's planetary models later.

Pla

Deferen