Chapter 1

Earth in the Solar System

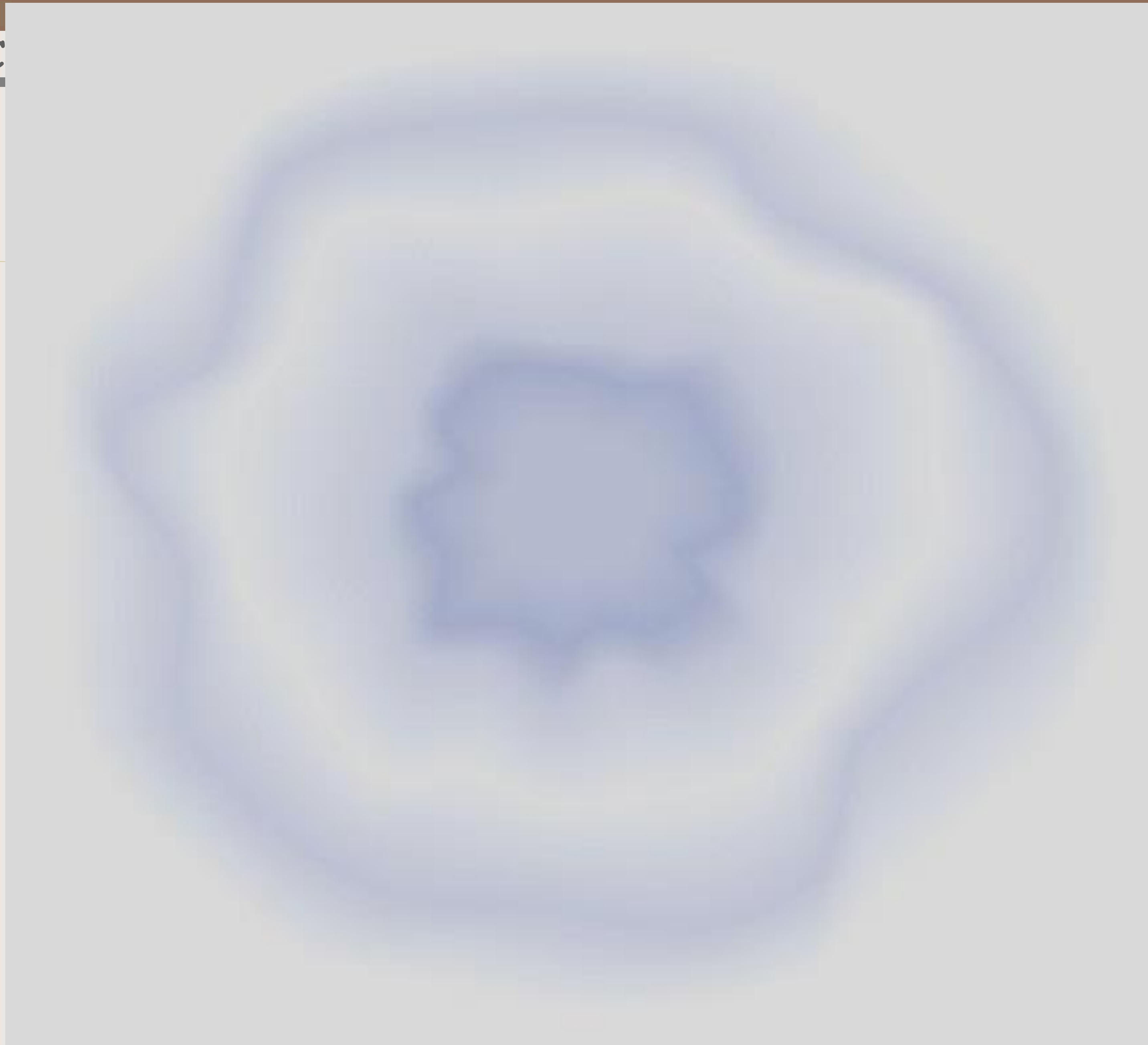
I. The Origin of the Universe

1. Big Bang (birth of the universe): Hydrogen and Helium were created

2. Nuclear fusion in stars: More Helium, also heavier elements, from Lithium to Iron

3. Supernovae: Everything heavier than Iron.

This happened mainly 15 to 20 B.Y. ago



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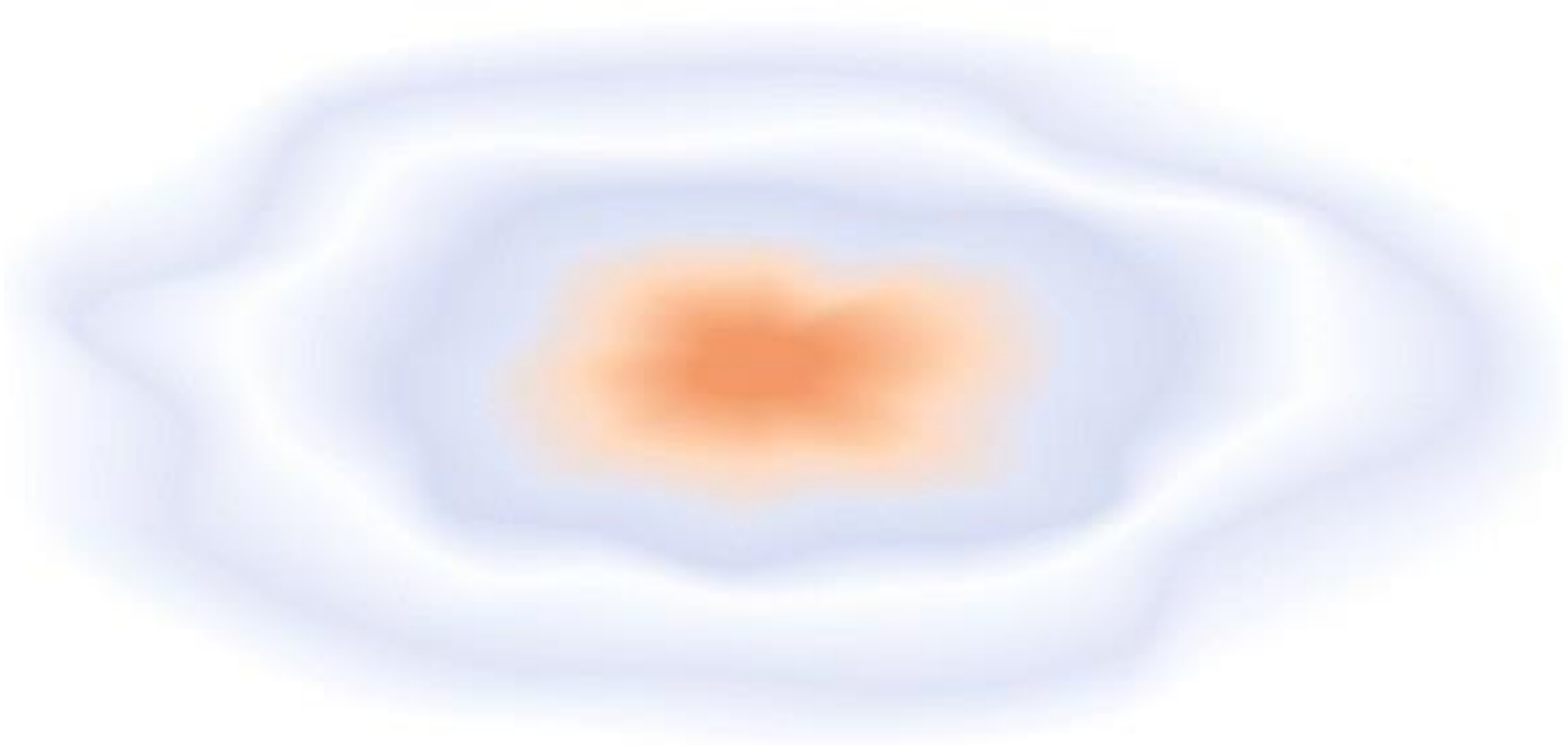

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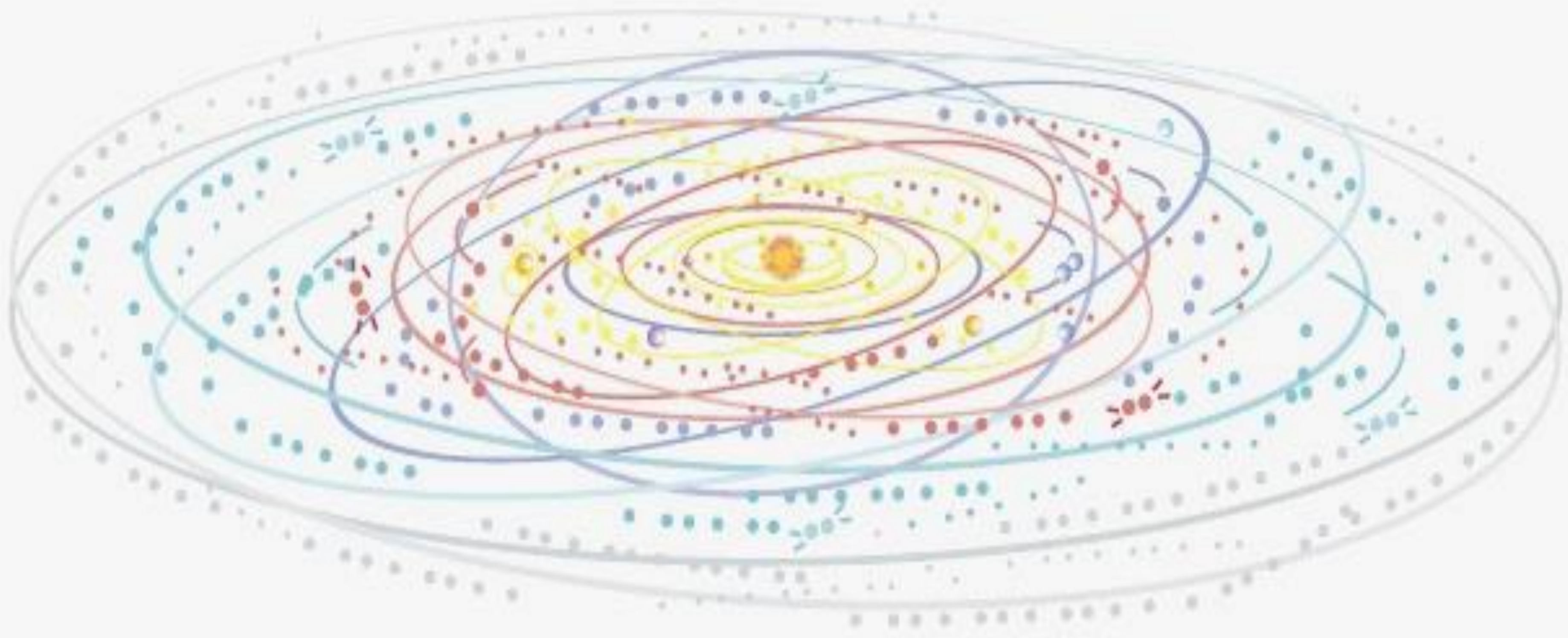

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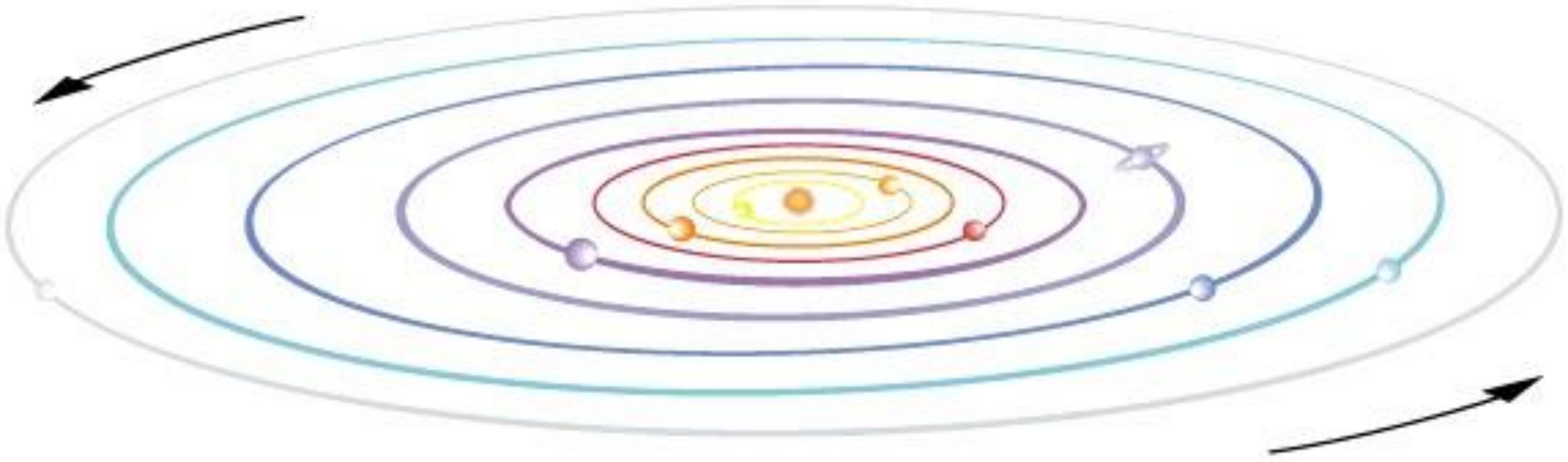

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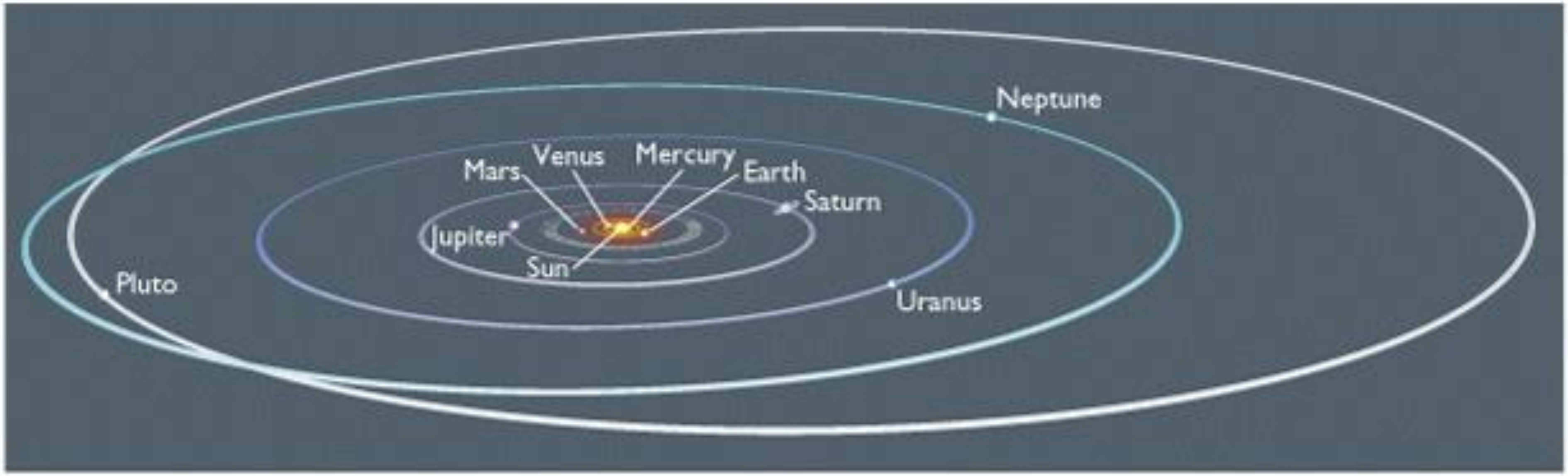
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Mars
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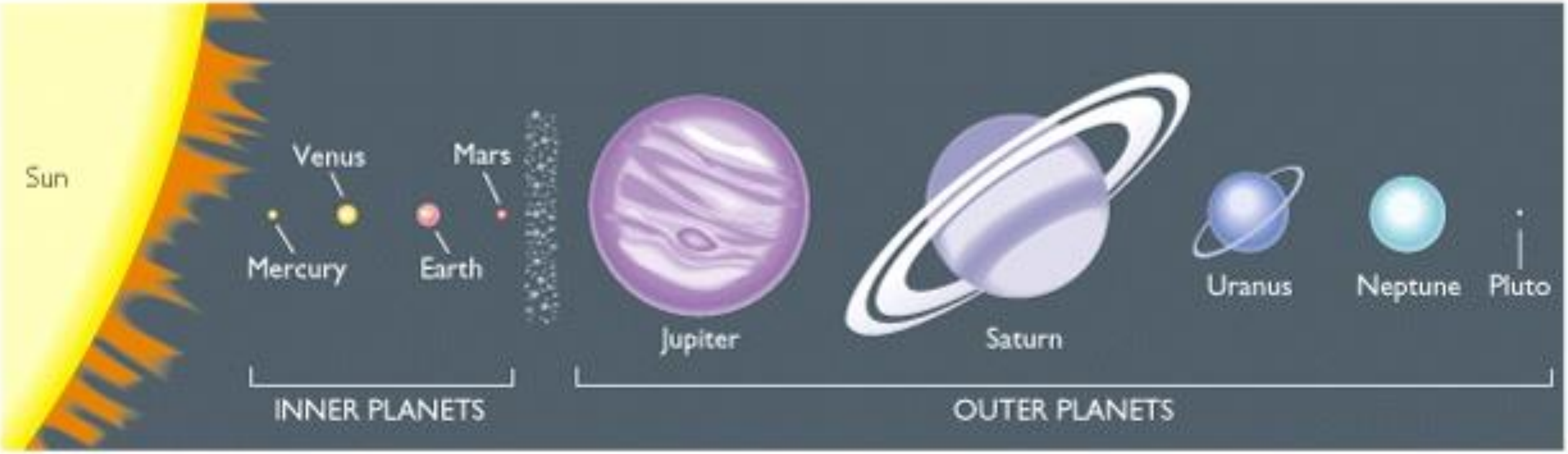

Sun
Venus
Mars
Mercury
Earth
Jupiter
Saturn
Uranus
Neptune
Pluto
INNER PLANETS
OUTER PLANETS

A. Formation of the Solar System

- The origin of the solar system could be traced to a rotating cloud of dust and gas.

This is known as the Nebular Hypothesis

- The gases that form these clouds are hydrogen and helium.
- The dust sized particles are chemically similar to materials found on earth..

A. Formation of the Solar System

- The diffuse slowly rotating cloud contracted under the force of gravity.
- This acceleration, in turn, accelerated the rotation of the particles, and the faster rotation flattened the cloud into a disk.

B. Stages in Evolution of the Sun:

1. Gravitational Contraction:

Initially, as gas molecules and particles of dust plunged toward the center to form the protosun, it started to shine brightly from the heat produced by their friction.

2. Nuclear fusion:

At a certain point, when pressure at the core of the protosun reached a critical point, (H) atoms began to fuse into (He), releasing thermonuclear energy.
As less stuff fell into the new sun, nuclear fusion replaced gravitational contraction as the primary source of solar heat.

II. Origin of the Planets

A. Accretion

As particles of dust in the planetary nebula encountered one another, they often stuck together due to electrostatic forces. These formed larger and larger aggregates called planetisimals.

B. Planetisimals

At a certain point, as clumps of materials became larger, gravity replaced electrostatic attraction as the dominant force.

Planetisimals "fell onto" one another forming planet-sized bodies. As these grew, some attracted gasses that formed primitive atmospheres.

II. Origin of the Planets

C. Solar wind:

As nuclear fusion became the sun's dominant power source, atoms on its surface became energized to the point that they began flying off of the sun's surface as a solar wind.

This wind swept the inner solar system clean of gas and dust.

The accretion of new planetisimals stopped.

III. Planetary Types:

1. Terrestrial Planets:

small (The Earth is the largest)

composed of rock and metals

with small atmospheres

These formed in the solar wind-swept inner solar system

III. Planetary Types:

2. Jovian planets:

large (tens to hundreds of times the mass of the Earth)

composed of (H) and (He), ices (volatile substances such as H_2O, CH_4, and NO^{3-}), rocks and metals

with massive atmospheres

These formed far enough from the sun that massive atmospheres of (H) and (He) could be trapped.

III. Planetary Types:

3. Asteroid Belt :

present between Mars and Jupiter

these represent the remnants of primitive material formed during the Big Bang

III. Planetary Types:

4. Meteorites :

represent material left over from the formation of the Solar System

they are 4.56 billion years old, → this is when the solar system condensed.

The sun's gravitational field also contains small bodies of frozen gases and cosmic material called comets

+

Small clusters of rocks known as meteoroids, and large quantities of cosmic dust, which are probable remnants of the Big Bang.

IV. Early History of the Earth

What happened in between the formation of the Solar System and the formation of the earliest rocks?

A. Sources of heat for the early Earth included:

1. Period of Gravitational heating.
   Earth's Interior: uniform and undifferentiated
   Earth's Exterior: being heated by impacting planetisimals yielding a magma ocean kilometers deep.

2. Giant Impact of a Mars-size planetisimals.
   All moon rocks are very depleted in volatile materials compared to Earth rocks. The remaining non-volatile stuff accreted to form the moon.

IV. Early History of the Earth

3. Radiogenic heating
is brought about by the decay of radioactive isotopes inside the Earth.

The first atmosphere had little or no free oxygen in it.

IV. Early History of the Earth

B. Period of Differentiation

The net effect of all heat sources was to melt or soften the Earth's interior enough to allow lighter materials to rise and heavier materials to sink.

This sinking caused more gravitational heating, accelerating the process.

A layered, differentiated Earth with heavier materials (mostly metals) at the center and lighter ones (mostly rocks) near the surface.

IV. Early History of the Earth

➢Differentiation yields three basic compositional layers of the Earth:

1. Crust

Light rocks rich in Si and Al ~ 10 to 70 km thick.

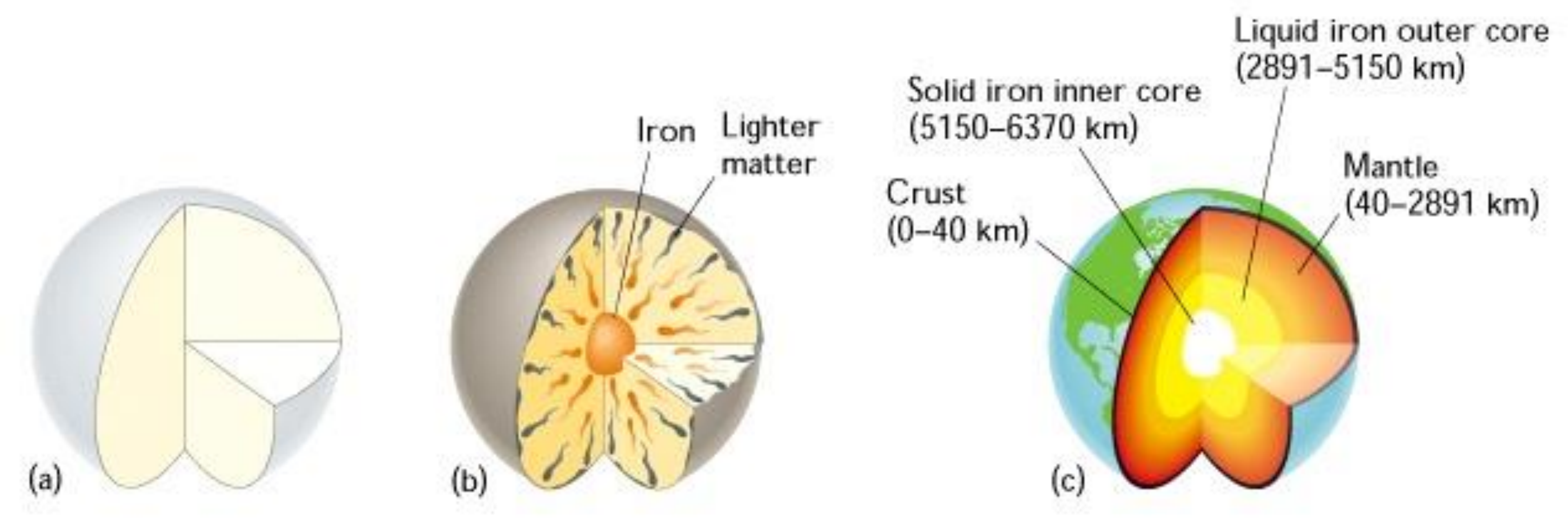
2. Mantle

Bottom of crust down to 2880 km. Dense rocks rich in Fe & Mg .

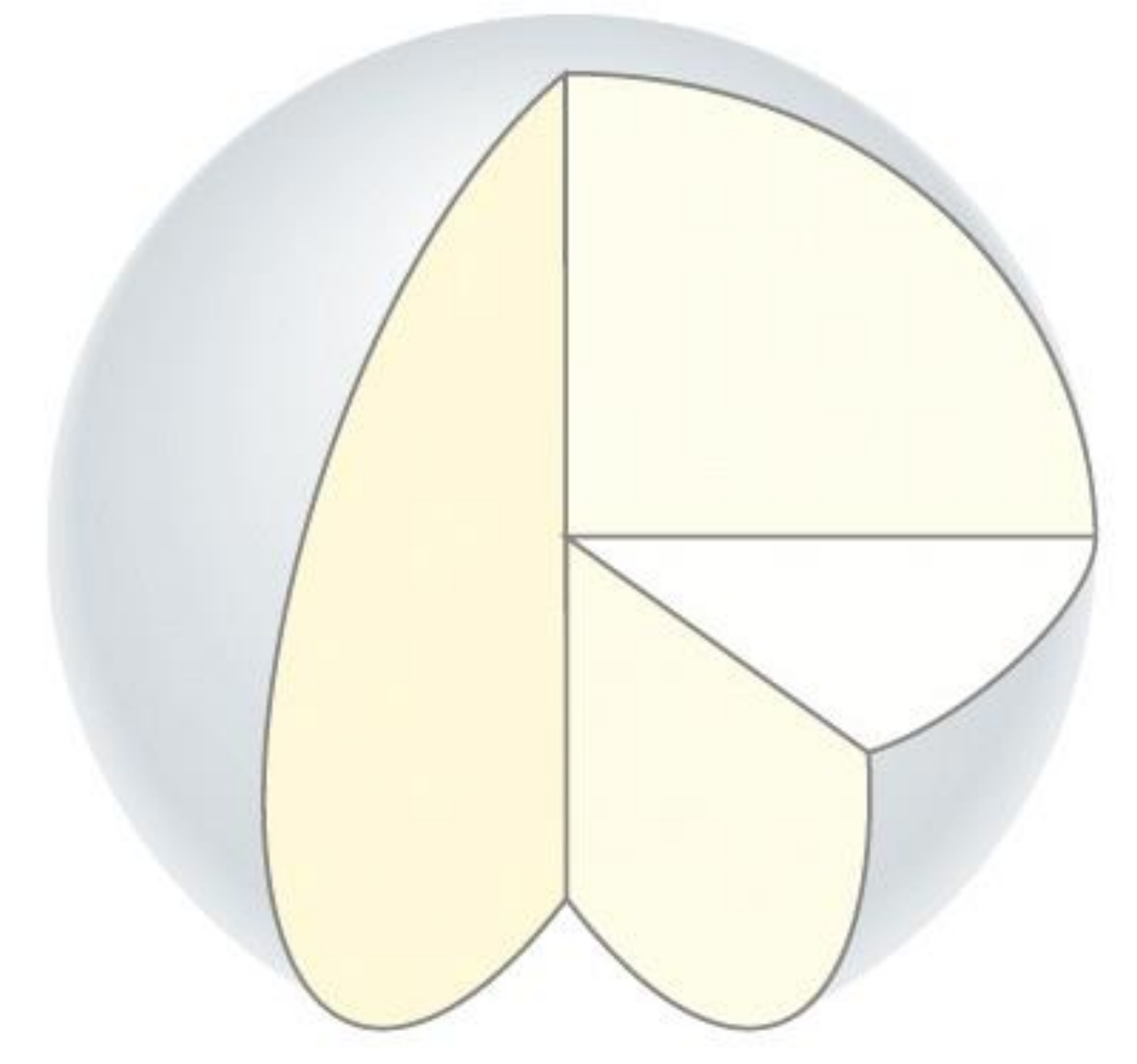
3. Core

From 2880 km. to the center. Metallic - primarily made up of Fe & Ni.

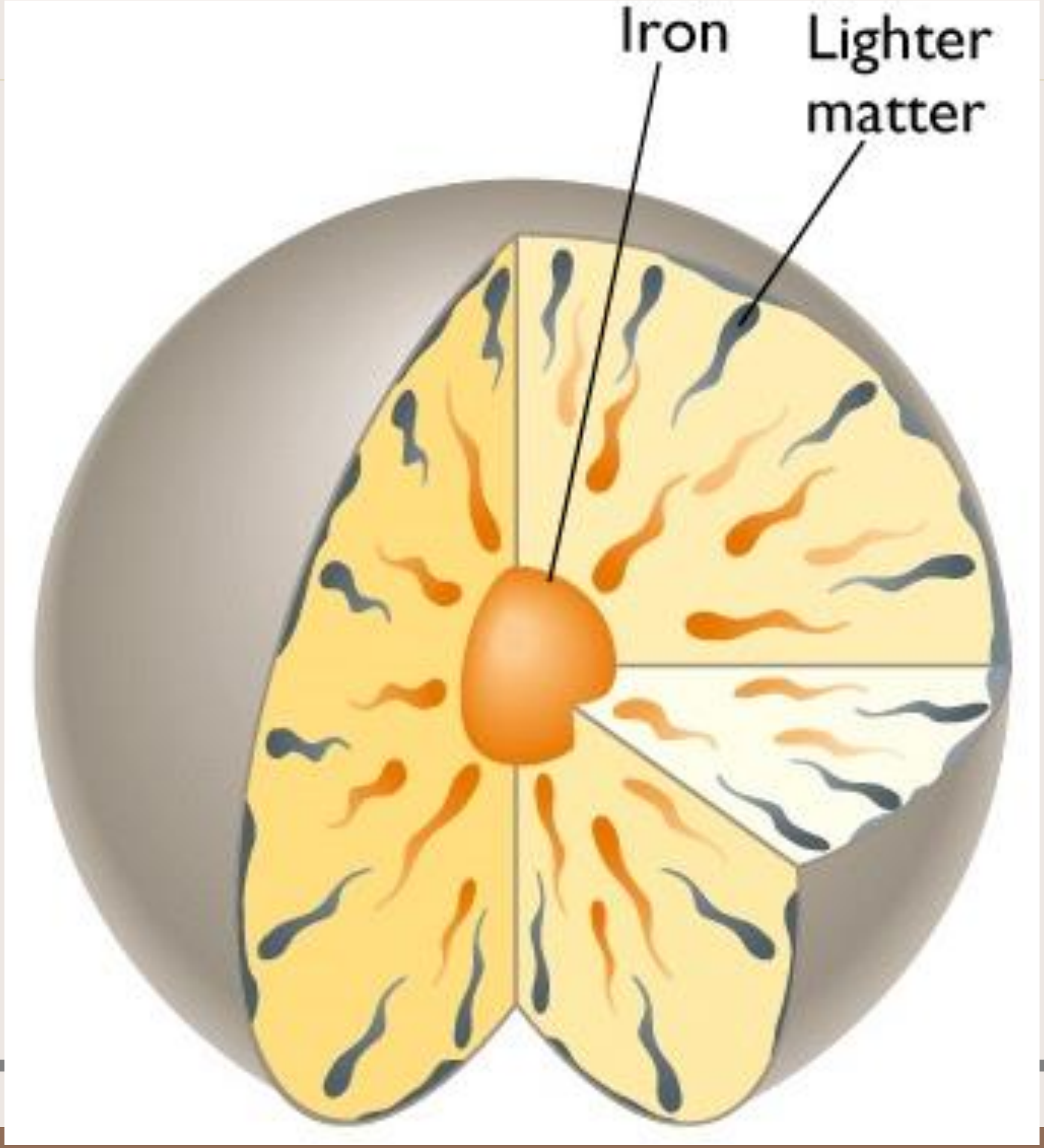
Differentiation of the Earth

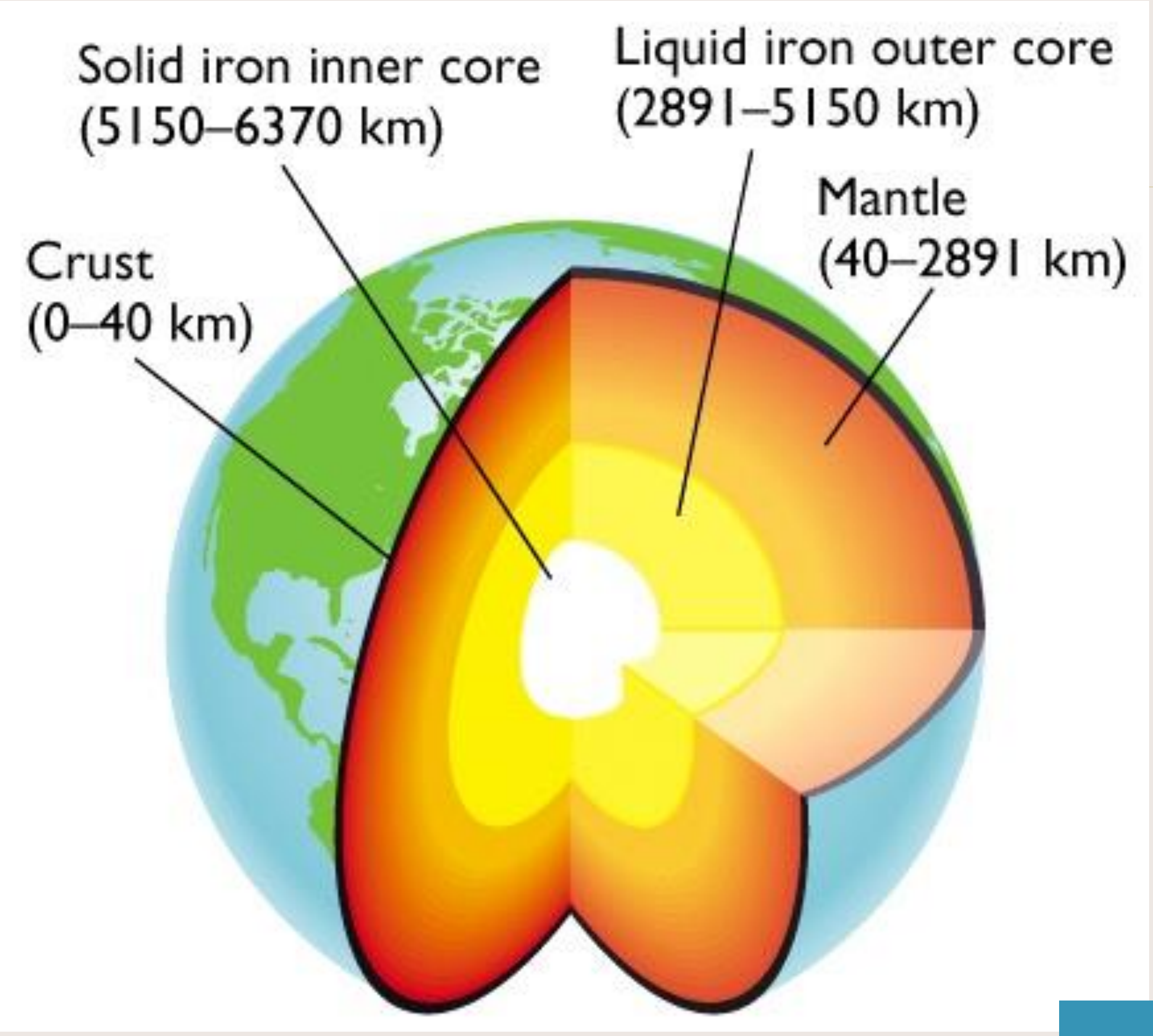


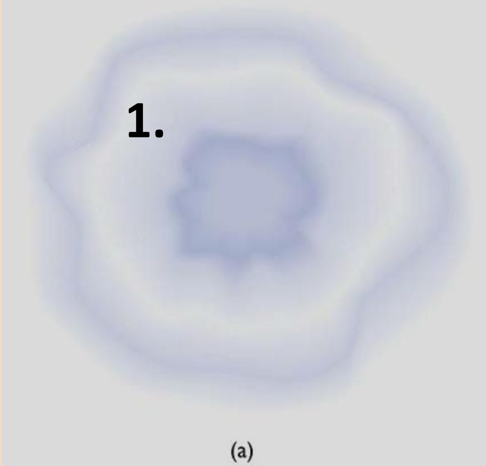
An Early Homogeneous Earth



Differentiation Begins




Solid iron inner core
(5150–6370 km)
Liquid iron outer core
(2891–5150 km)
Mantle
(40–2891 km)
Crust
(0–40 km)



- Pictures from the *Hubble Space Telescope* show **newborn stars emerging from dense, compact pockets of interstellar gas**.
- Analogous to the formation of our solar system

evaporating gaseous globules

Lecture 1 Questions

How old is the Universe?

A) Between 15-20 MY (million years)

B) 1 B.Y (billion years)

C) Between 15-20 B.Y (billion years)

Lecture 1 Questions

What is the most accepted theory of the Universe Origin?

A) Nebulose theory

B) Big Bang theory

C) Gravity and pressure

D) Power of light

Lecture 1 Questions

What is the most accepted theory of the origin of our Solar System?

A) Nebulose theory
B) Big Bang theory
C) Gravity and pressure
D) Power of light

Lecture 1 Questions

How old is our Solar system?

A) Between 5-4.5 MY (million years)

B) 10 B.Y (billion years)

C) Between 5-4.5 B.Y (billion years)

Lecture 1 Questions

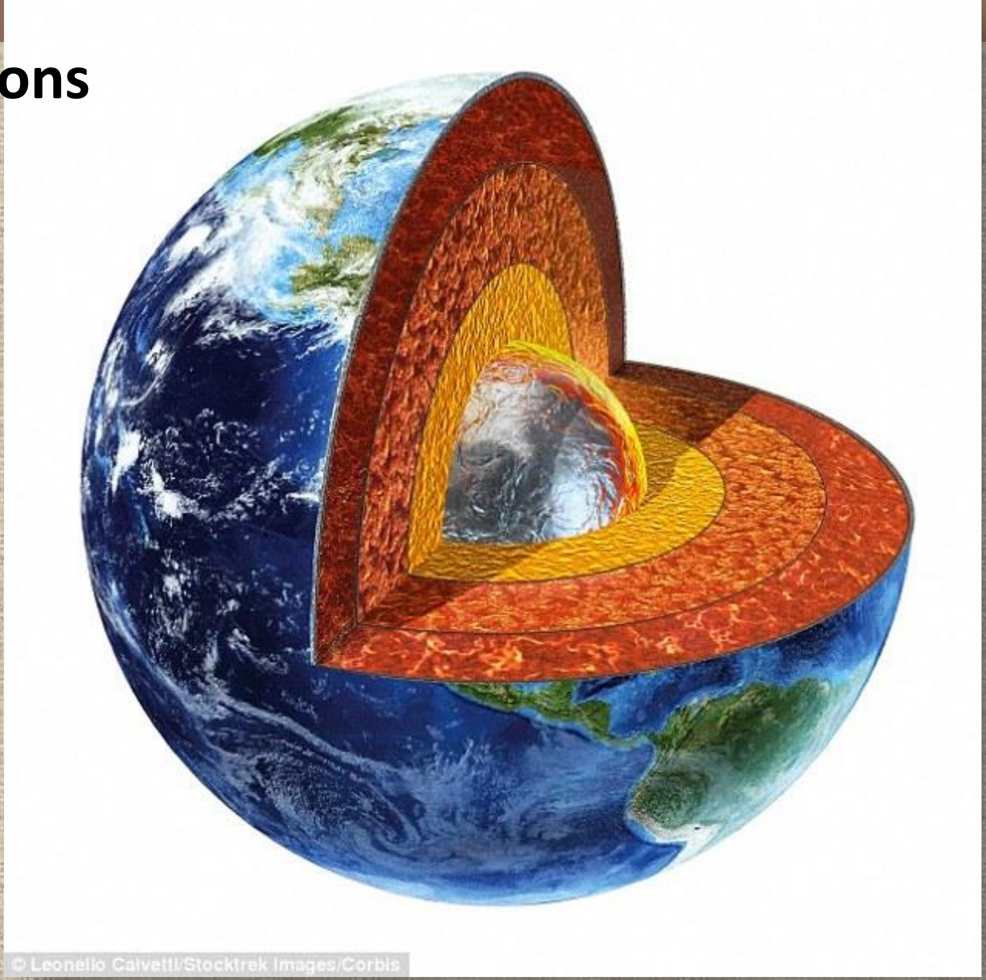
How old is the Earth?

A) 4.6 MY (million years)

B) 10 B.Y (billion years)

C) 4.6 B.Y (billion years)

Lecture 1 Questions



The different compositional zones of the earth are…

A) Hydrosphere, lithosphere, biosphere and atmosphere

B) Crust and Atmosphere

C) Core, Mantle and crust

IV. Early History of the Earth

- Earth's stratification is similar to other terrestrial planets in that it has:
  - a. **Lithosphere:** Stratified solid material
  - b. **Atmosphere:** Gaseous envelope
- Earth differs from other planets in having:
  - a. **Hydrosphere:** creating differences
  - b. **Biosphere:** the aggregate of living things which interact strongly with other Earth systems.

These are the major subsystems of the dynamic Earth System with Earth Cycles like water cycle, rock cycle (carbon cycle) and tectonic cycles.

IV. Early History of the Earth

- The heating and subsequent differentiation of the early Earth led to the formation of the atmosphere and the oceans.

The first atmosphere had little or no free oxygen in it.

The Evolving Atmosphere

➢ **Humans** could **not** have **survived** in the **early atmosphere**.

- **Volcanic** out-gassing create a **thicker atmosphere** composed of a **wide variety of gases**
- The gases were probably **similar to** those created by **modern volcanic eruptions**

The Evolving Atmosphere

These would include:

- **Water vapor (H_2O)**
- Sulfur dioxide (SO_2)
- Hydrogen sulfide (H_2S)
- Carbon dioxide (CO_2)
- Carbon Monoxide (CO)
- Ammonia (NH_3)
- Methane (CH_4)

The Evolving hydrosphere

Scientists believe that liquid water on earth (oceans) has **two possible origins**:

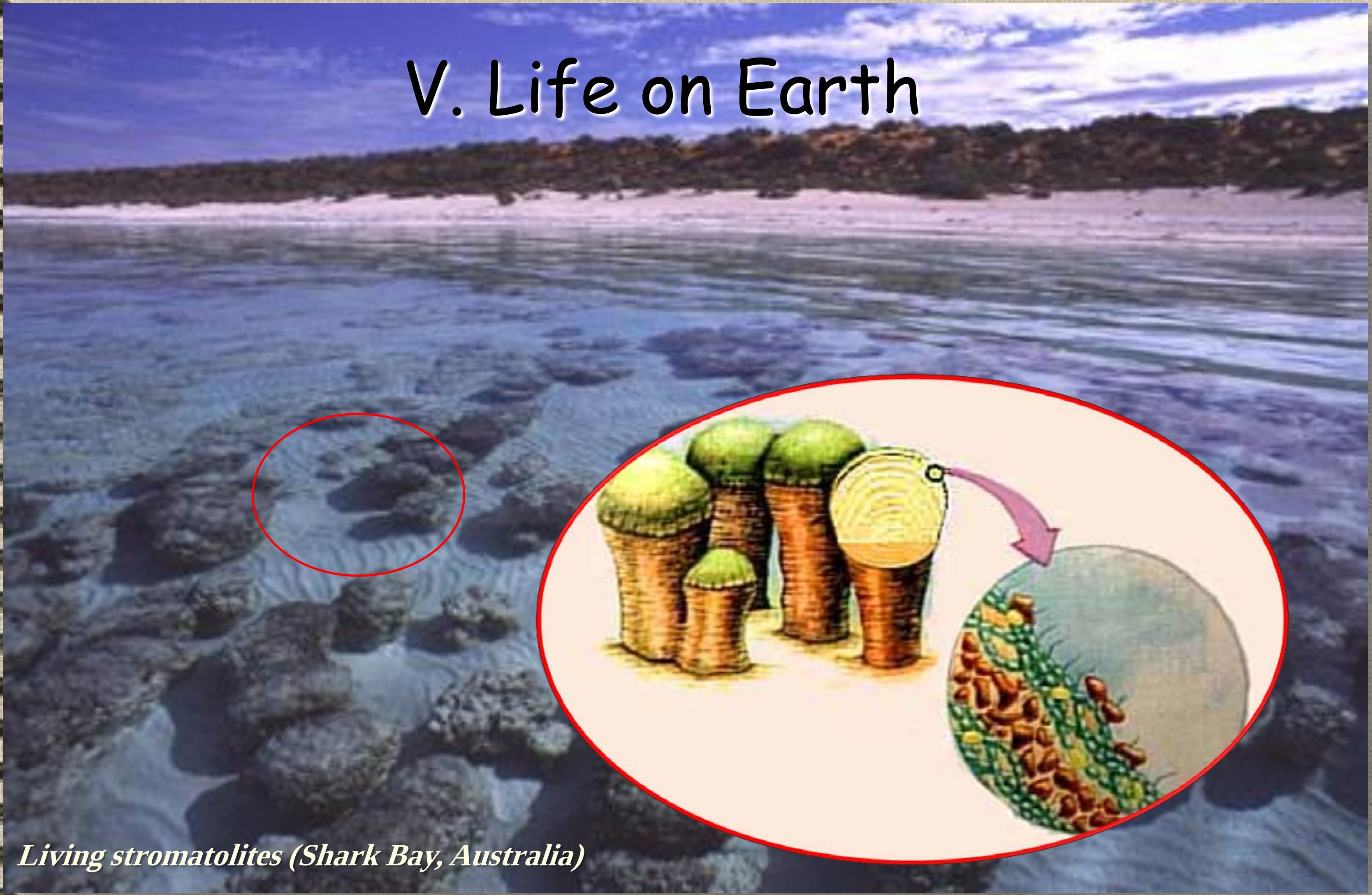
- Water vapor (H_2O) added by continuous **volcanic eruptions** throughout billions of years.
- Extraterrestrial impacts (meteorites with **high ice content**).

V. Life on Earth

- **Life on earth** as we know it was **not possible before** the single-celled blue-green algae appeared in significant numbers to modify the atmosphere around 1 billion years ago.
- **Their structures** are abundant in the Geological record. Very old forms of life still alive.

Stromatolites. They have been recovered from very old sedimentary rocks (Archean, **3.5 billions of years ago**)

V. Life on Earth

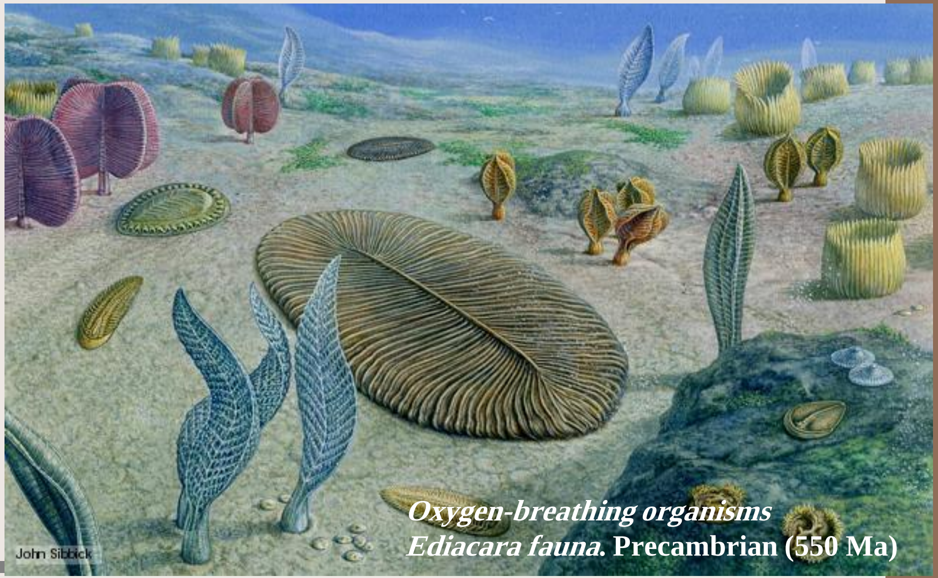


Living stromatolites (Shark Bay, Australia)

- **Stromatolites** are **layered mounds**, columns, and sheet-like **sedimentary rocks**. They were **originally formed** by the **growth of layer upon layer of cyanobacteria**

V. Life on Earth

- They **used the sunlight energy to convert the carbon dioxide (CO_2) into O_2** through photosynthesis.
- With **time**, enough **oxygen accumulated** and Earth was able to **support oxygen-breathing organisms** on its surface



Oxygen-breathing organisms
Ediacara fauna. Precambrian (550 Ma)

V. Life on Earth

■ TABLE 1.1 Composition of the Atmosphere Near the Earth's Surface

PERMANENT GASES			VARIABLE GASES			
Gas	*Symbol*	*Percent (by Volume) Dry Air*	*Gas (and Particles)*	*Symbol*	*Percent (by Volume)*	*Parts per Million (ppm)**
Nitrogen	N_2	78.08	Water vapor	H_2O	0 to 4	
Oxygen	O_2	20.95	Carbon dioxide	CO_2	0.038	380*
Argon	Ar	0.93	Methane	CH_4	0.00017	1.7
Neon	Ne	0.0018	Nitrous oxide	N_2O	0.00003	0.3
Helium3	He	0.0005	Ozone	O_3	0.000004	0.04**
Hydrogen	H_2	0.00006	Particles (dust, soot, etc.)		0.000001	0.01–0.15
Xenon	Xe	0.000009	Chlorofluorocarbons (CFCs)		0.00000002	0.0002

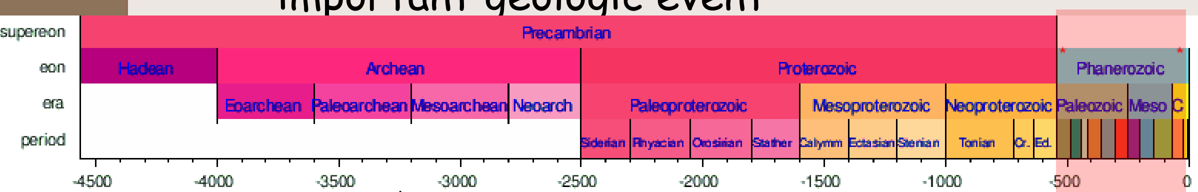
*For CO_2, 380 parts per million means that out of every million air molecules, 380 are CO_2 molecules.

**Stratospheric values at altitudes between 11 km and 50 km are about 5 to 12 ppm.

V. Life on Earth

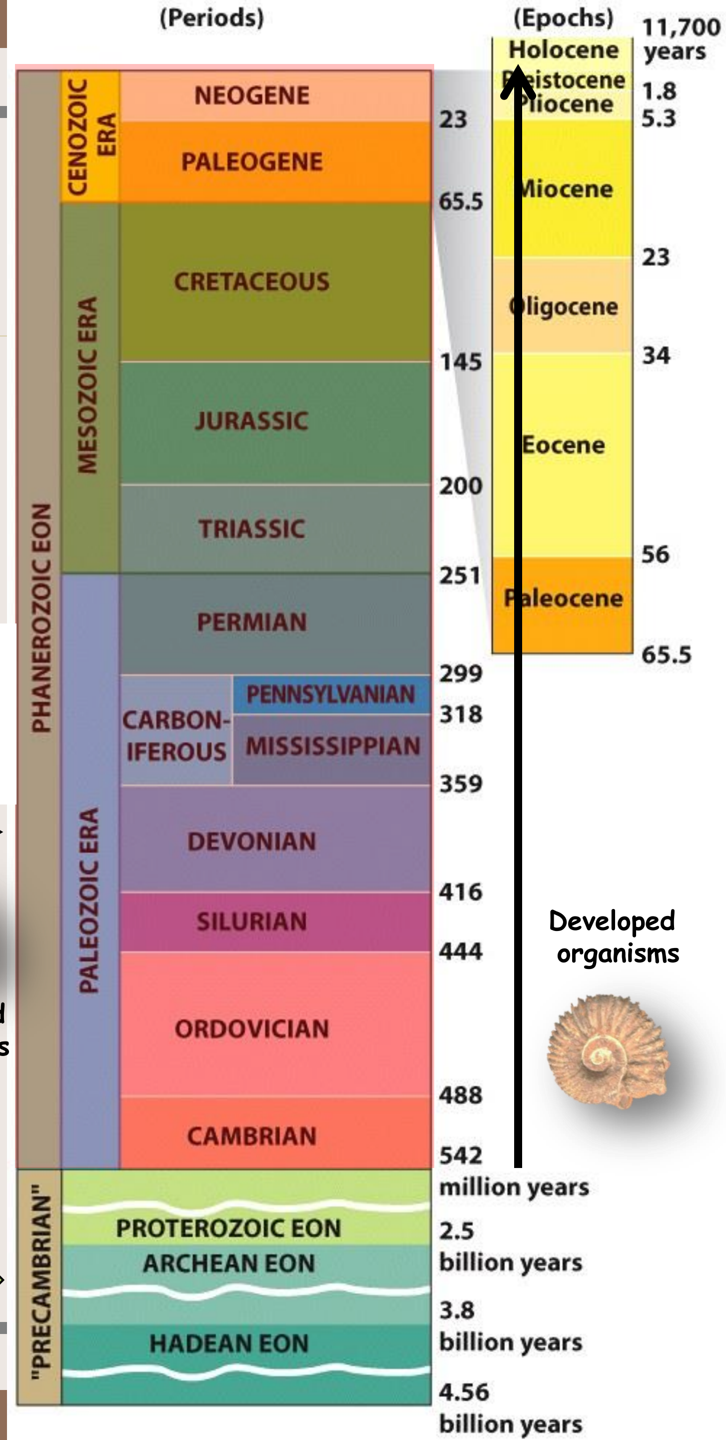
Geologists divided the Earth history in different units: **Eons, Eras, Periods and Epochs.**

- Each boundary is usually related to an important geologic event

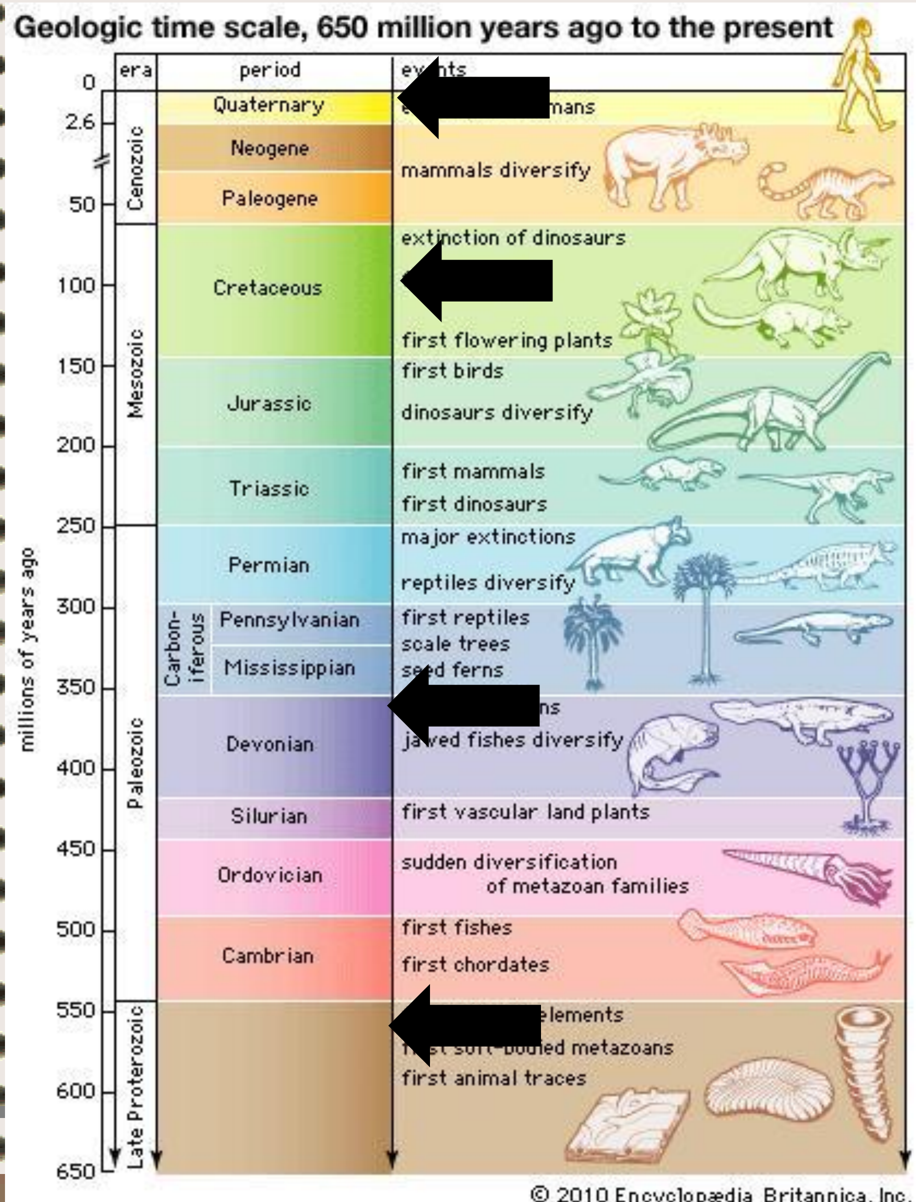


Developed organisms

Stromatolites



C. Life on Earth




Humans


Dinosaurs

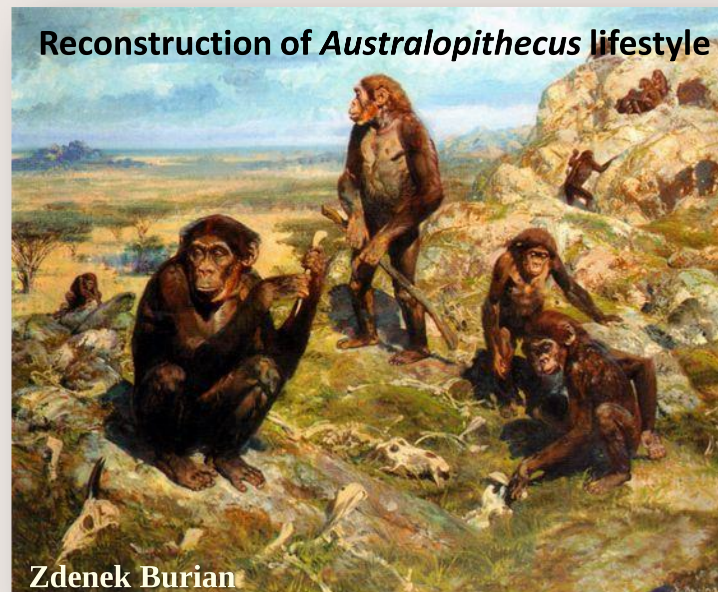

First amphibians (tetrapod)

Ediacara fauna

V. Life on Earth

- The most primitive hominid remains are not older than **2 to 3 million years ago**.
-

Lucy. 3.2 Ma. *Australopithecus afarensis* Ethiopia.

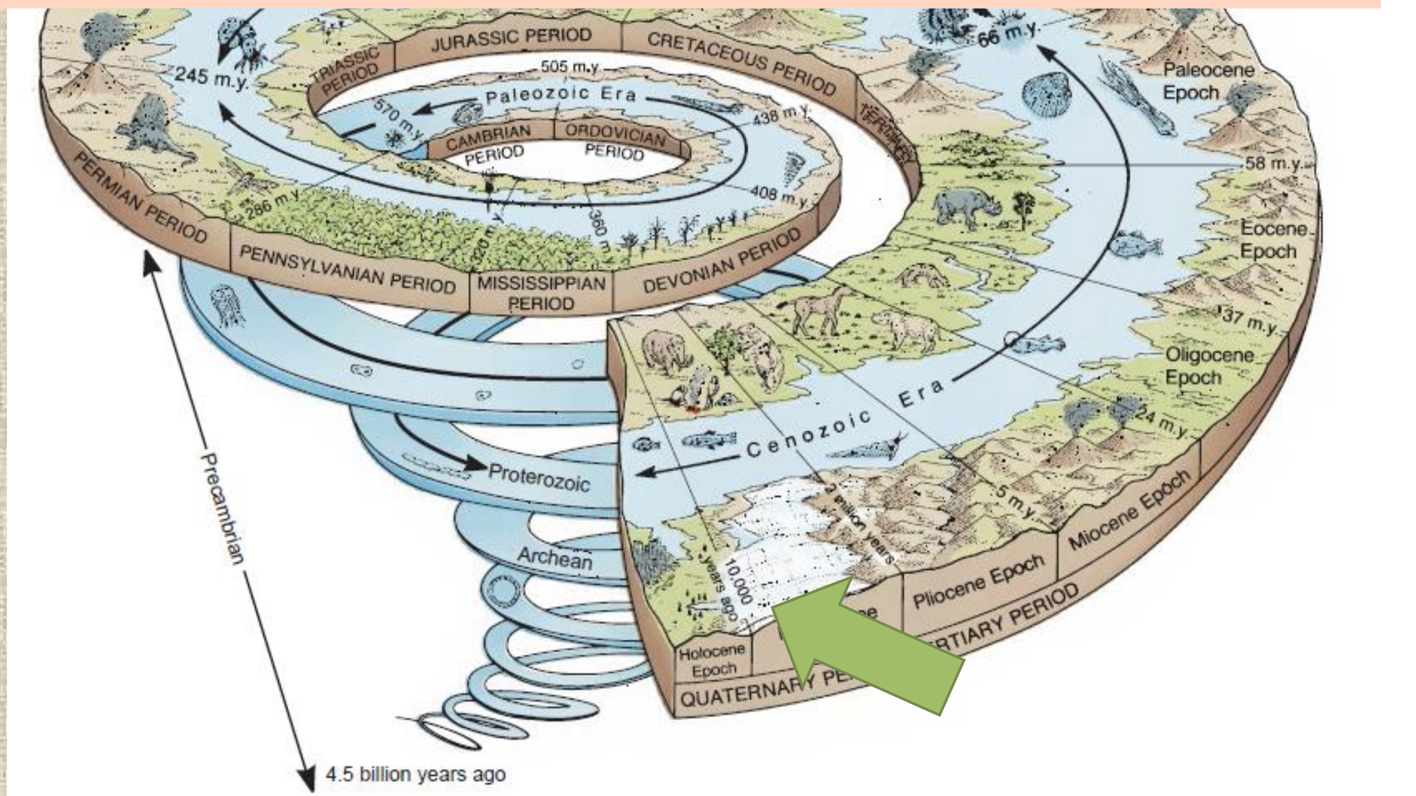


- The modern **rational humans** (*Homo sapiens*) developed only about half a million years ago.

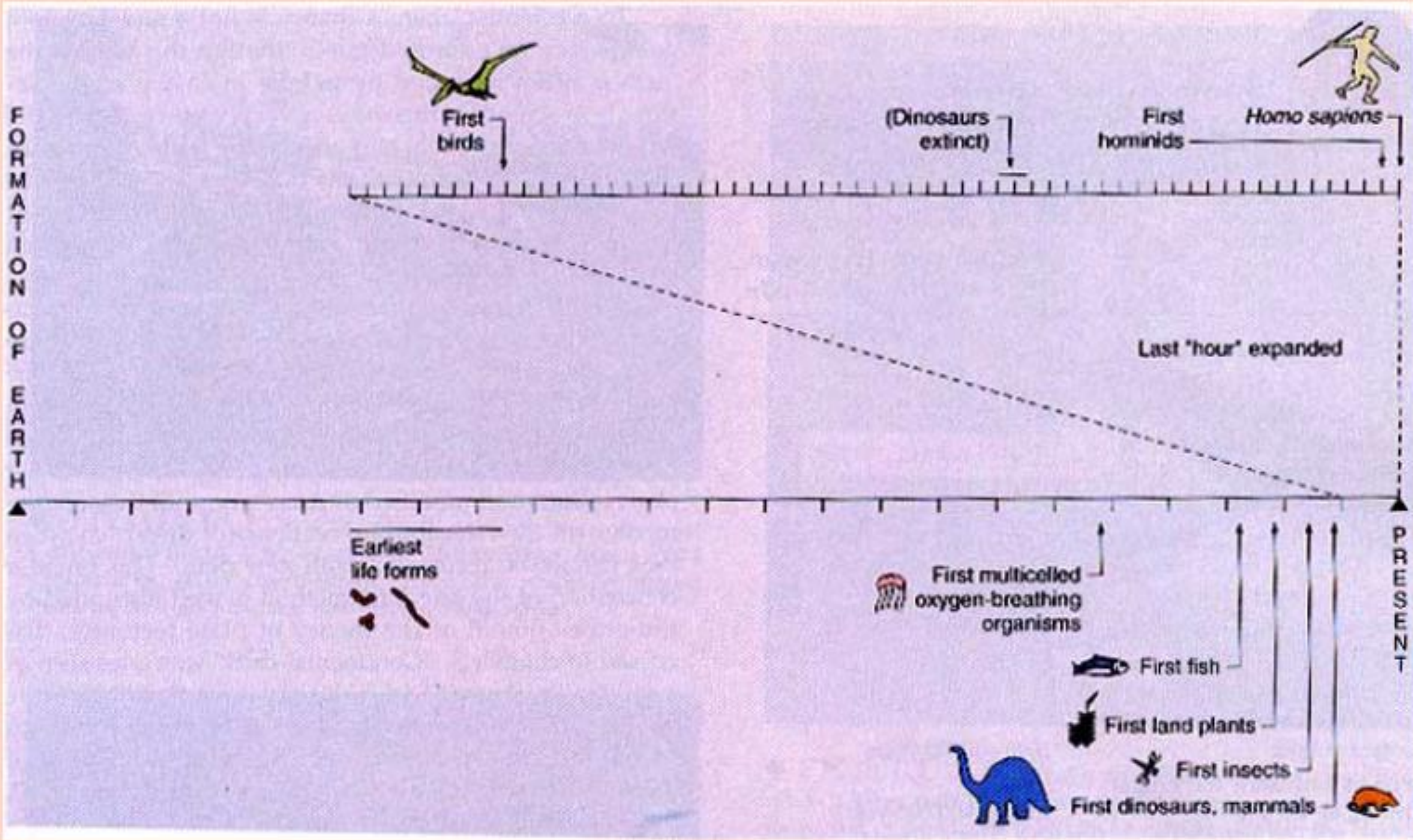
C. Life on Earth

In a geologic sense

Humans are quite a new "addition" to the Earth systems; however, their impact has been very large.



The "geologic spiral": Important plant and animal groups appear where they first occurred in significant numbers. If earth's whole history were equated to a 24-hour day, modern thinking humans (*Homo sapiens*) would have arrived on the scene just about ten seconds ago.



If **Earth's history** is equated to a **24 hr day**, (each **"hour"** equals about **190 million** years), modern thinking humans (**Homo sapiens**) arrived about **10 seconds** ago!

VI. The Geologic Perspective

- **Geology** was mainly a **descriptive science** involving careful observation of natural processes and their products.
- The subject **has become** both more **quantitative** and **more interdisciplinar**.

> ➢ ***Geology*** is especially <u>challenging</u> owing to the difference between a **scientist's laboratory** and **nature's "laboratory"**.

VI. The Geologic Perspective

How it was formed?

What strengths has acted to fold these rocks?

VI. The Geologic Perspective

The Andes are a large volcanic chain of mountains that run the length of the west coast of South America.

What strengths has acted to carry these rocks to 6 km above the sea level?

VI. The Geologic Perspective

What strengths has acted to originate this debris flow?

VI. The Geologic Perspective

Ash pours from Mount St. Helens, May 1980.

How to monitor volcanic eruptions…

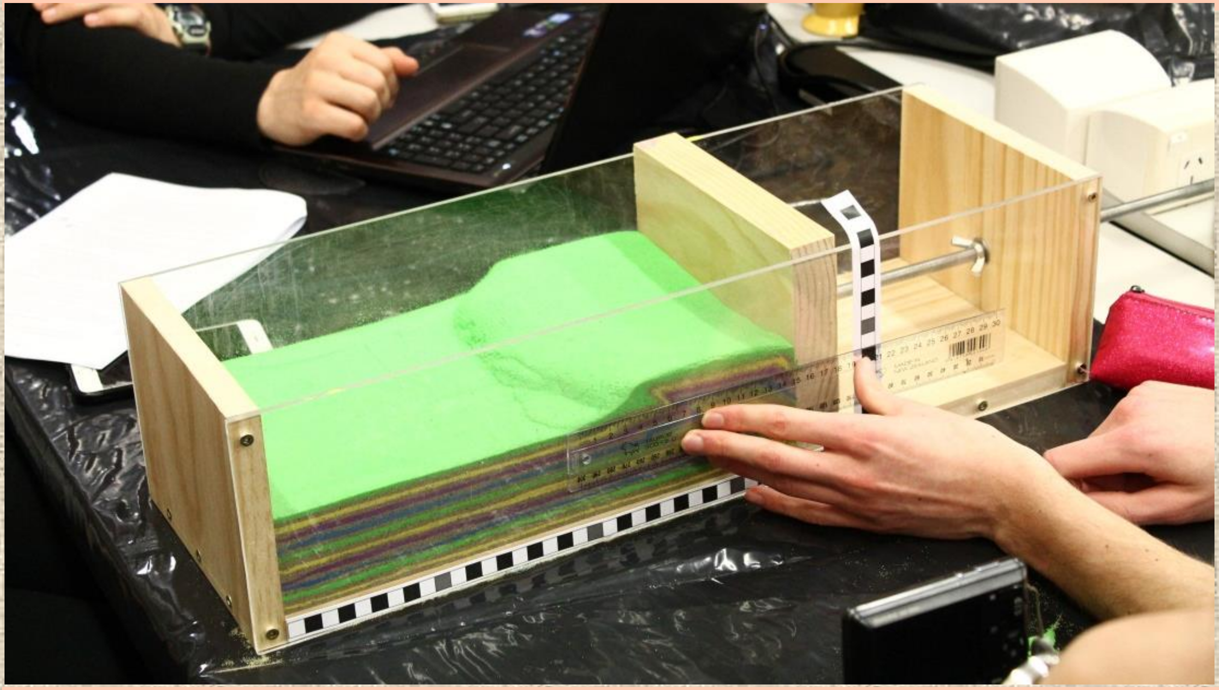
VI. The Geologic Perspective

Mississippi floods in Jefferson city, Missouri (USA). summer 1993.

How can we prevent floods? Plan where we have to build….

VI. The Geologic Perspective

- In a lab, one <u>controls</u> virtually all the ***<u>factors</u>*** of the experiment.



Sandbox experiments used to model the formation of mountains. Rock deformation lab

- In nature, however, the geologist is often confronted with <u>the **results** of the "experiment"</u> and has <u>to **deduce** the initial conditions</u> and the <u>processes involved</u>.

VI. The Geologic Perspective

- *Time* is another complicating factor.
- Natural geologic processes may take millions, even billions of years to achieve a particular result.
- While the laboratory time scale is calibrated in terms of hours, days, and months
- The geologic perspective also relies on the *scientific method*.

relying on *experiments*

VI. The Geologic Perspective

The scientific method

One starts with a set of measurements or observations or data.

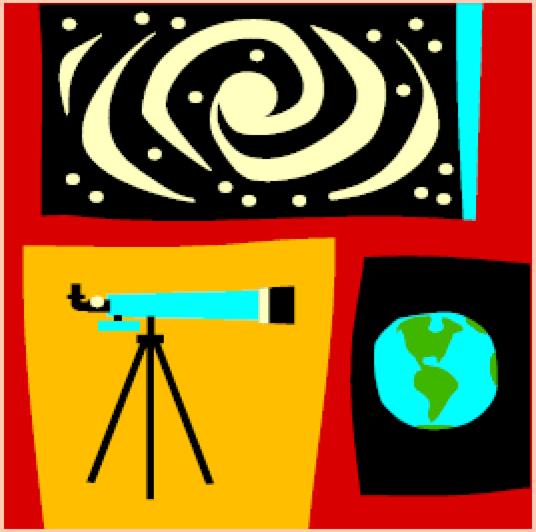
Then, some hypotheses are formulated to explain the observations.

- **Hypotheses** are then tested.
- When a **hypothesis** is repeatedly supported by new experiments, it eventually becomes a ***theory***.

A theory is: a generally accepted *explanation* for a **set of data** or observations.

VI. The Geologic Perspective

Why are we interested in <u>solving</u> geologic problems?



VI. The Geologic Perspective

➢ The motivation to find answers is stimulated by:

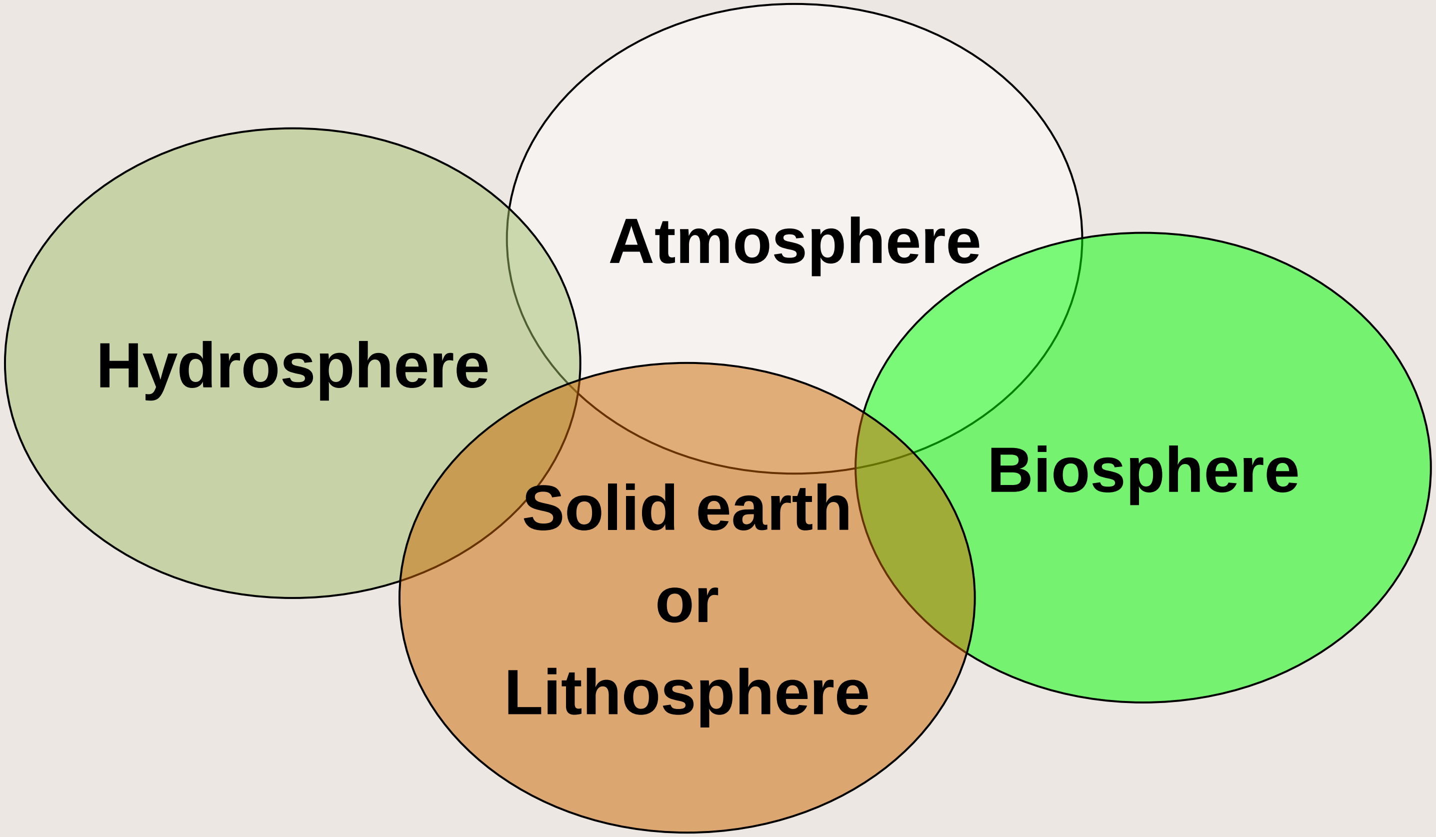
✓ The quest for knowledge

✓ The practical problems created by geologic hazards (natural disasters)

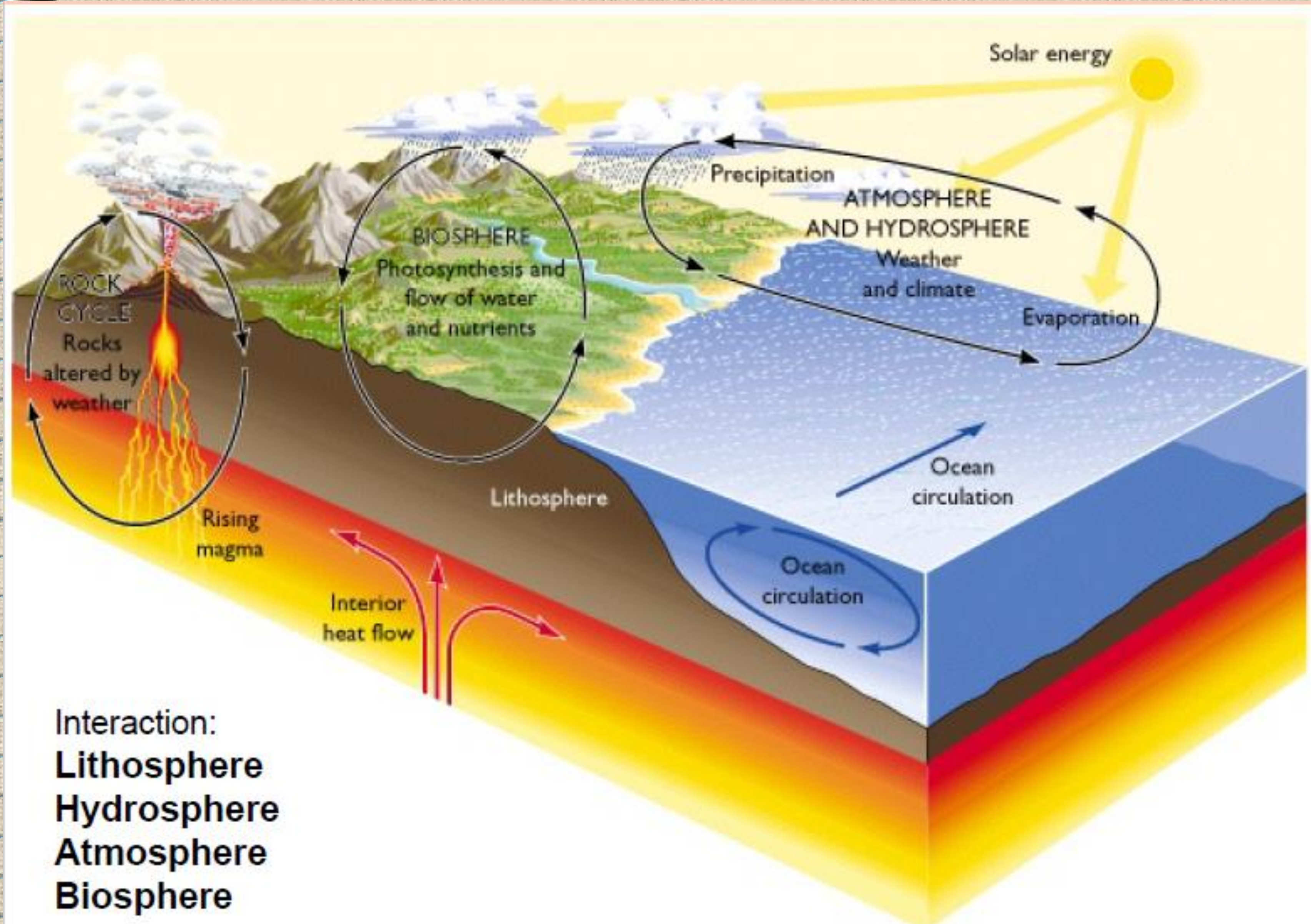
✓ The need for resources

VI. The Geologic Perspective

Earth consist of **4 major interacting spheres**



VI. The Geologic Perspective



VI. The Geologic Perspective

Earth cycles and Systems

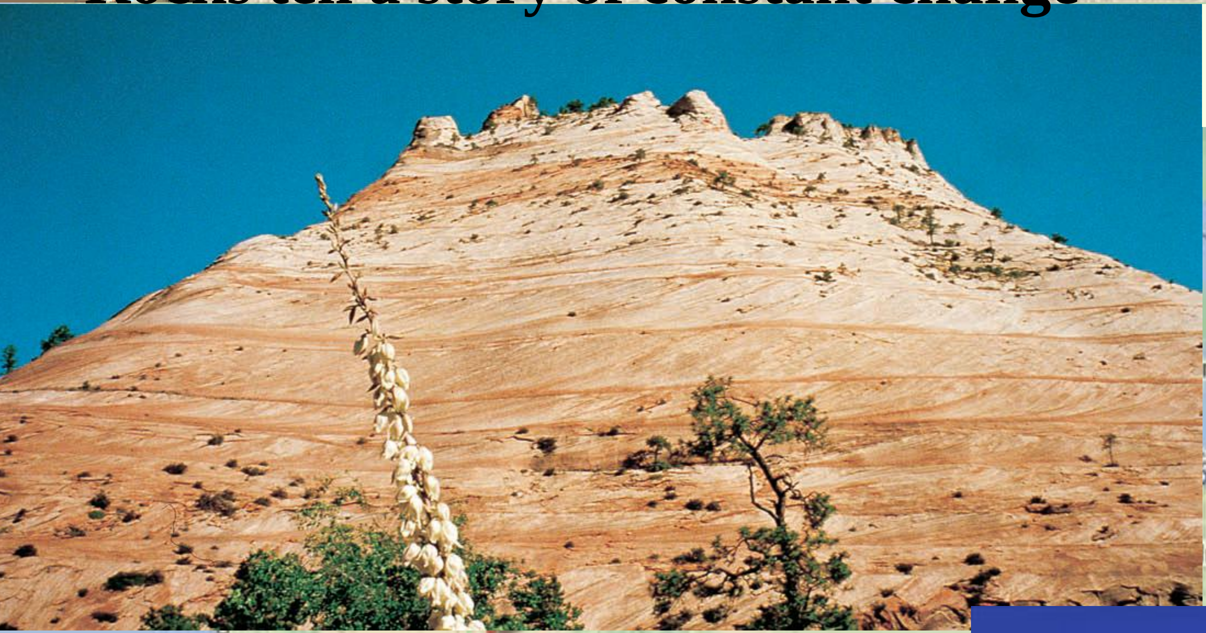
- The Earth is a dynamic and constantly changing planet.

- Many of the processes occurring on Earth are cyclic in nature.
  - ✓ The **rock** cycle
  - ✓ The **hydrologic** (water) cycle
  - ✓ **Chemicals** cycling through the environment.

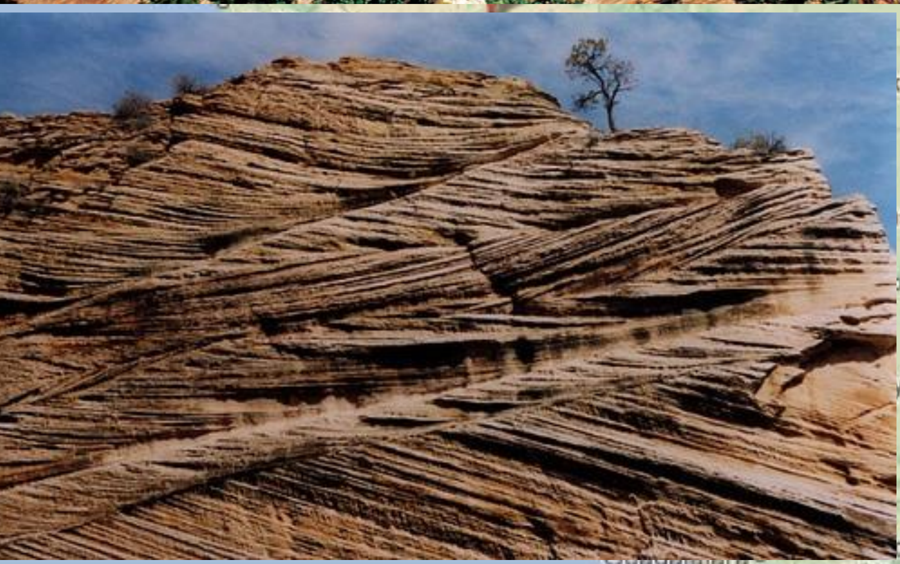
- These cycles are often interrelated.

C. The Geologic Perspective

Rocks tell a story of constant change

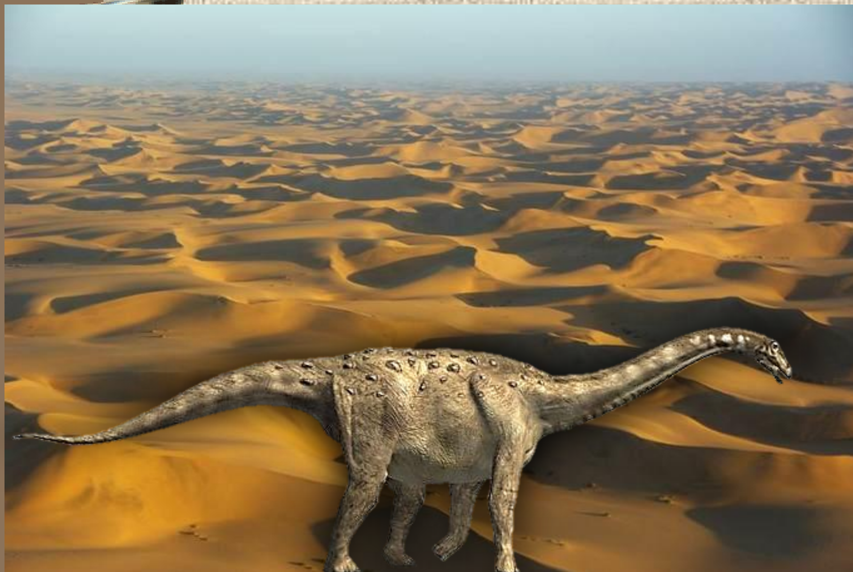


The sandstones of Zion National Park preserve ancient wind dunes (desert)



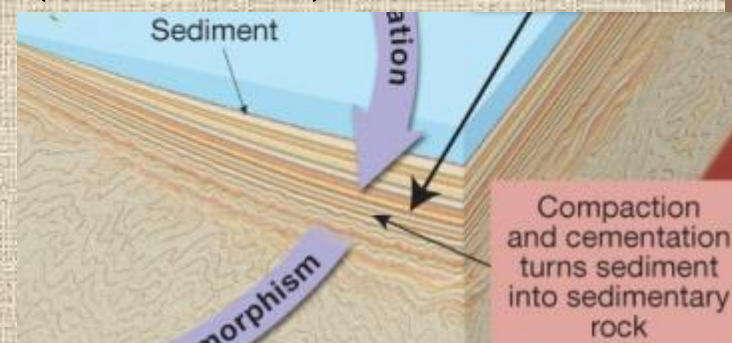
E.g. Sandstones of Zion National Park (Utah, USA)

E.g. Zion Sandstones



Sand of Zion (Jurassic,~150 Ma). Huge desert.

Original **sediments** (sand) deeply **buried and solidified** into new rock (Sandstone)



Sandstones, uplifted to erode again. Creating beautiful landscapes

Formation of the Moon