Vocabulary

Big Bang Theory

Nebular Theory

Star

Planet

Protoplanet

Solar Nebula

The History of the Earth

Origin of the Universe

- The universe began about 14.4 billion years ago
- The **Big Bang Theory** states that, in the beginning, the universe was all in one place
- All of its matter and energy were squished into an infinitely small point, a singularity
- Then it exploded

Origin of the Universe

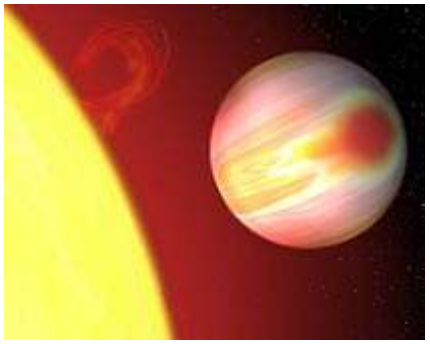
- The tremendous amount of material blown out by the explosion eventually formed the stars and galaxies
- After about 10 billion years, our solar system began to form

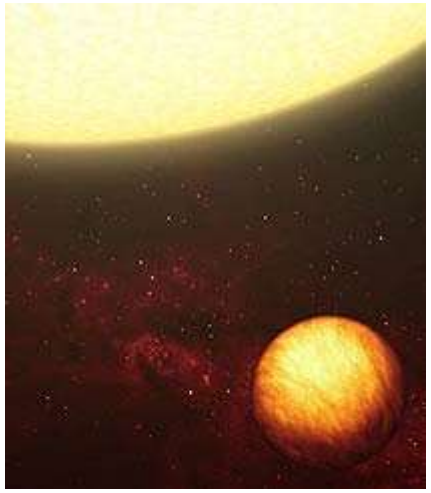
Birth of the Solar System

- We know how the Earth and Solar System are today and this allows us to work backwards and determine how the Earth and Solar System were formed
- Plus we can look out into the universe for clues on how stars and planets are currently being formed

Other Solar Systems

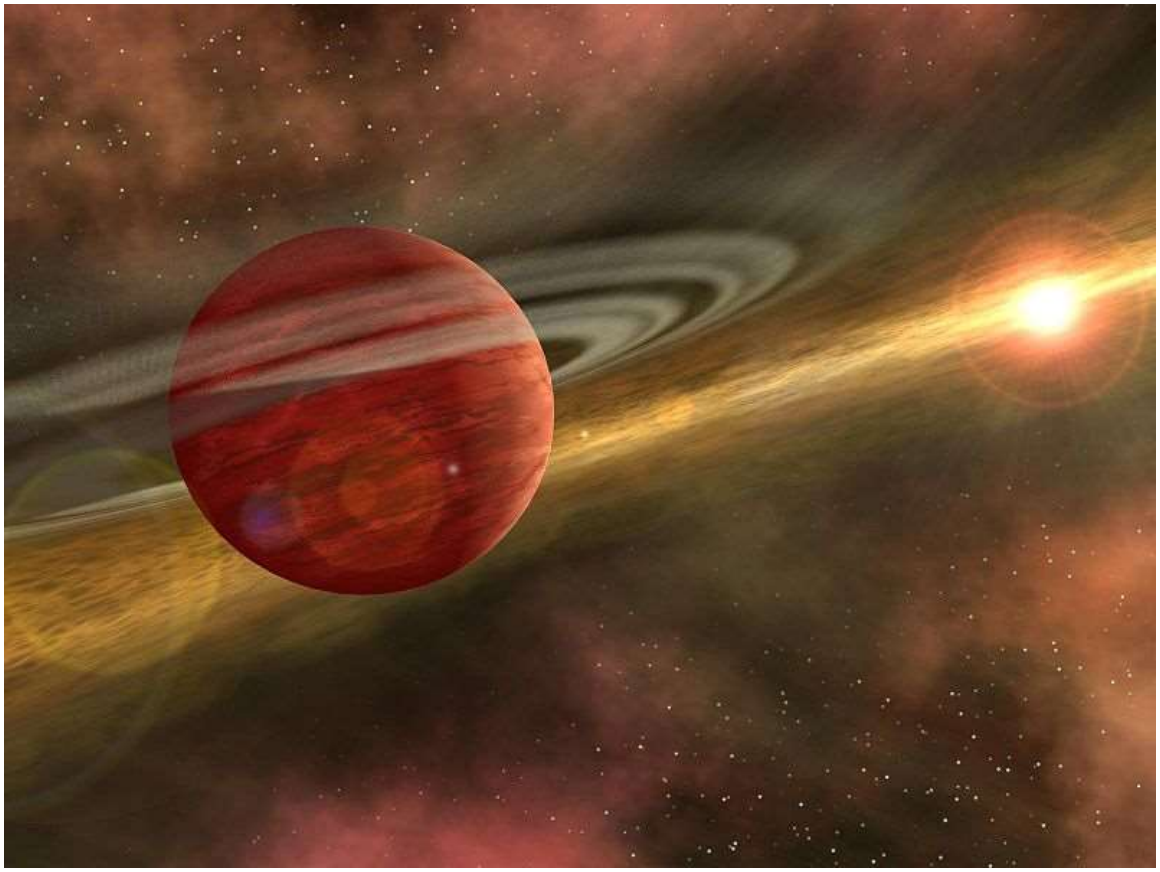
- We have now discovered over two hundred planets orbiting other stars
- The processes that created our solar system have also created an uncountable number of other solar systems





The Nebular Hypothesis

The Nebular Hypothesis is the Sun and the planets condensed out of a spinning cloud of gas and dust.



The Nebular Hypothesis

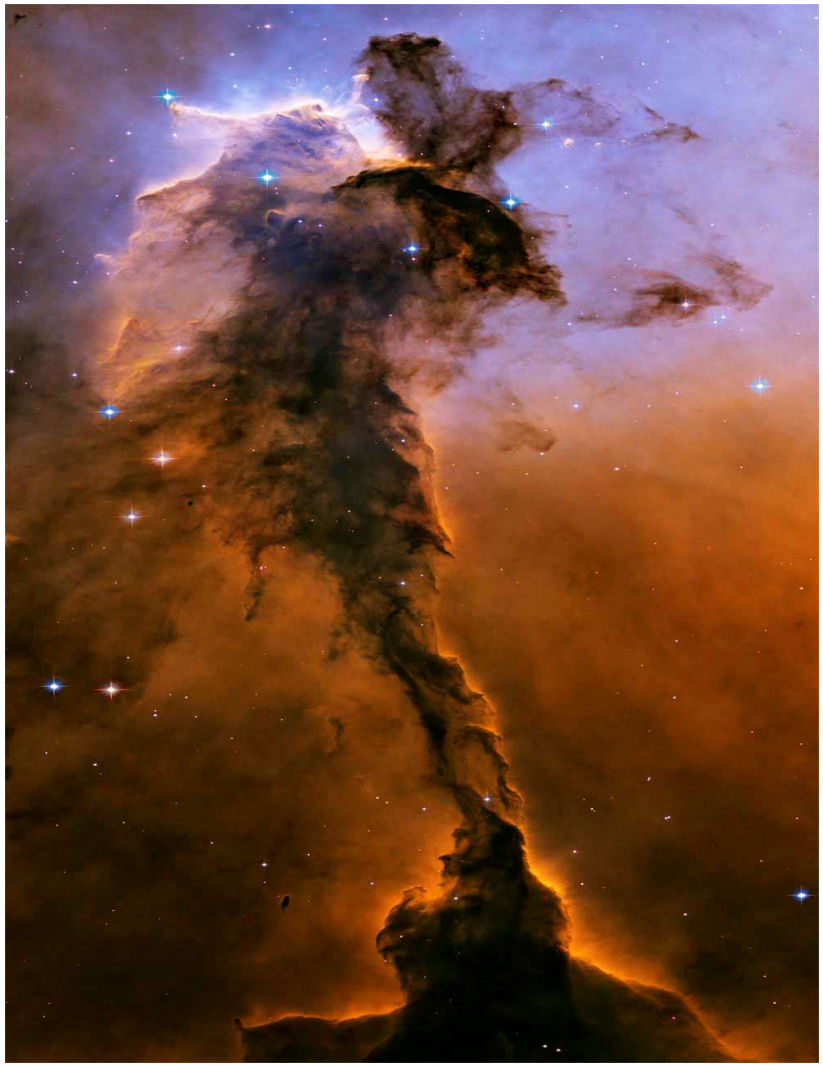
- A large gas cloud (nebula) begins to condense
- Most of the mass is in the center, there is turbulence (motion) in the outer parts

The Nebular Hypothesis

- Gravitational attraction causes the mass of gas and dust to slowly contract and it begins to rotate
- The dust and matter slowly falls towards the center

The Nebular Hypothesis

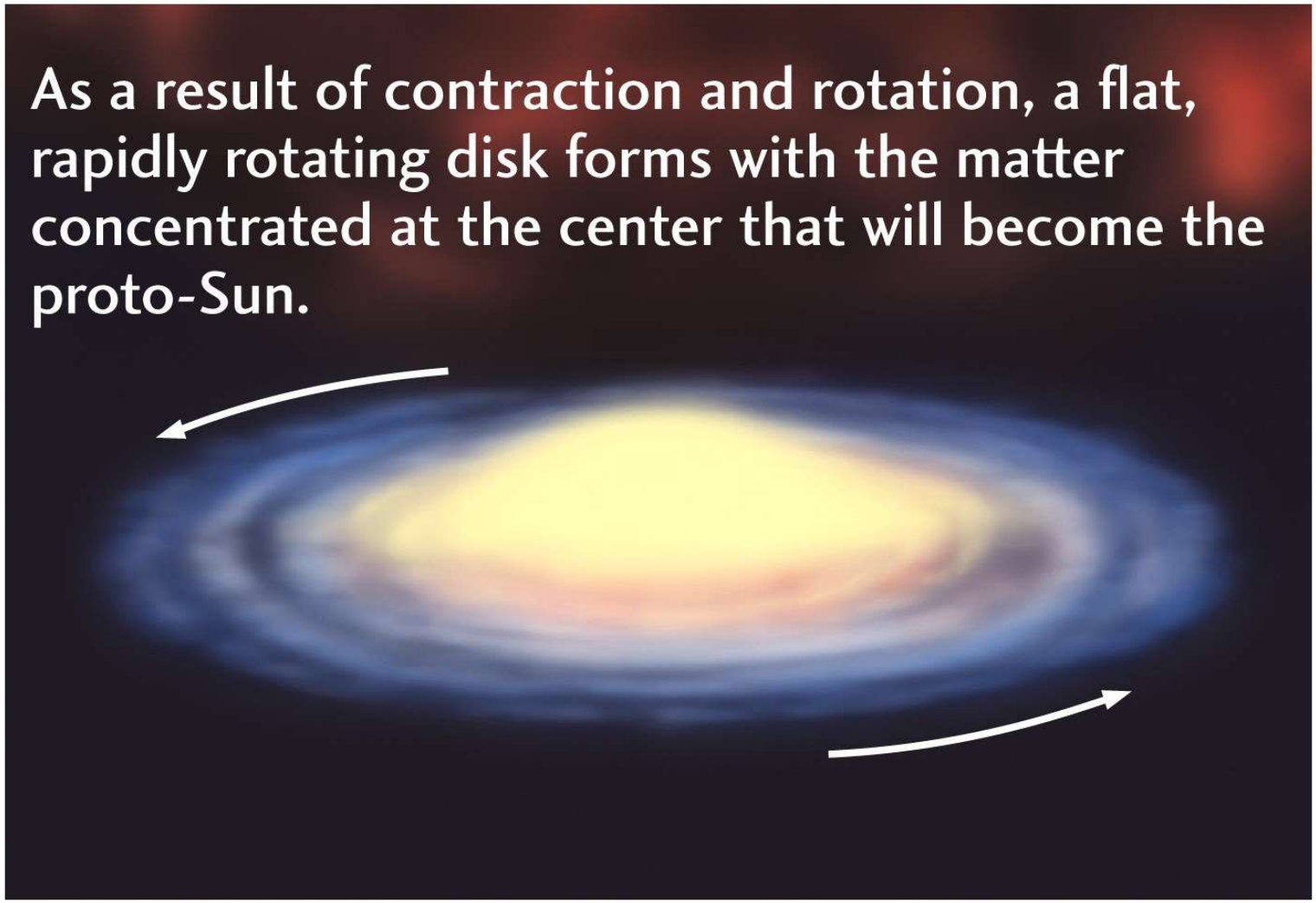
- Small chunks grow and collide, eventually becoming larger chunks



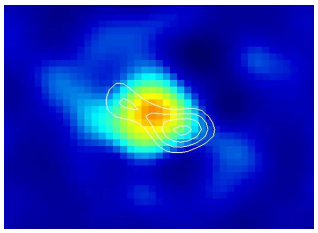
The Nebular Hypothesis

Pictures from the Hubble Space Telescope show newborn stars emerging from dense, compact pockets of interstellar gas called evaporating gaseous globules

Protostar


As a result of contraction and rotation, a flat, rapidly rotating disk forms with the matter concentrated at the center that will become the proto-Sun.

False Color Image of Protostar



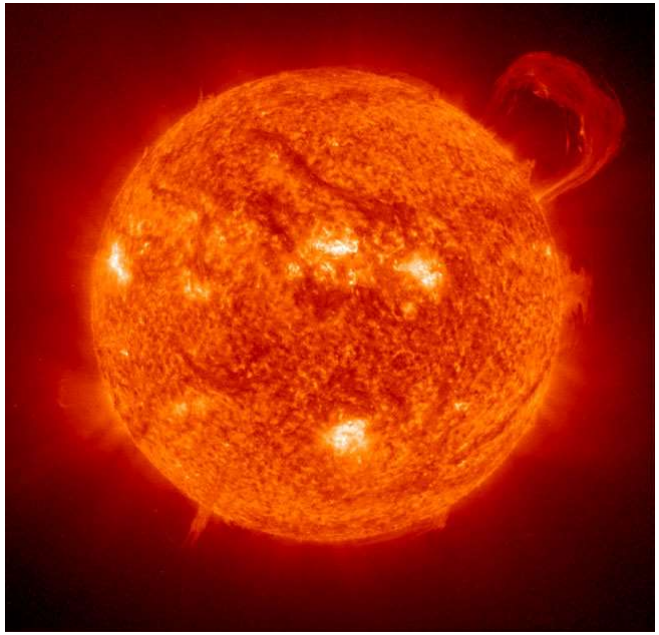
- The multi-colored area shows a dust disk surrounding a newborn star
- The red-orange area at the center represents the brightest region, which contains the young star
- It is surrounded by the cooler, dusty disk, which appears as yellow, green and blue
- The diameter of the disk is about 20 times larger than our entire solar system

The Sun

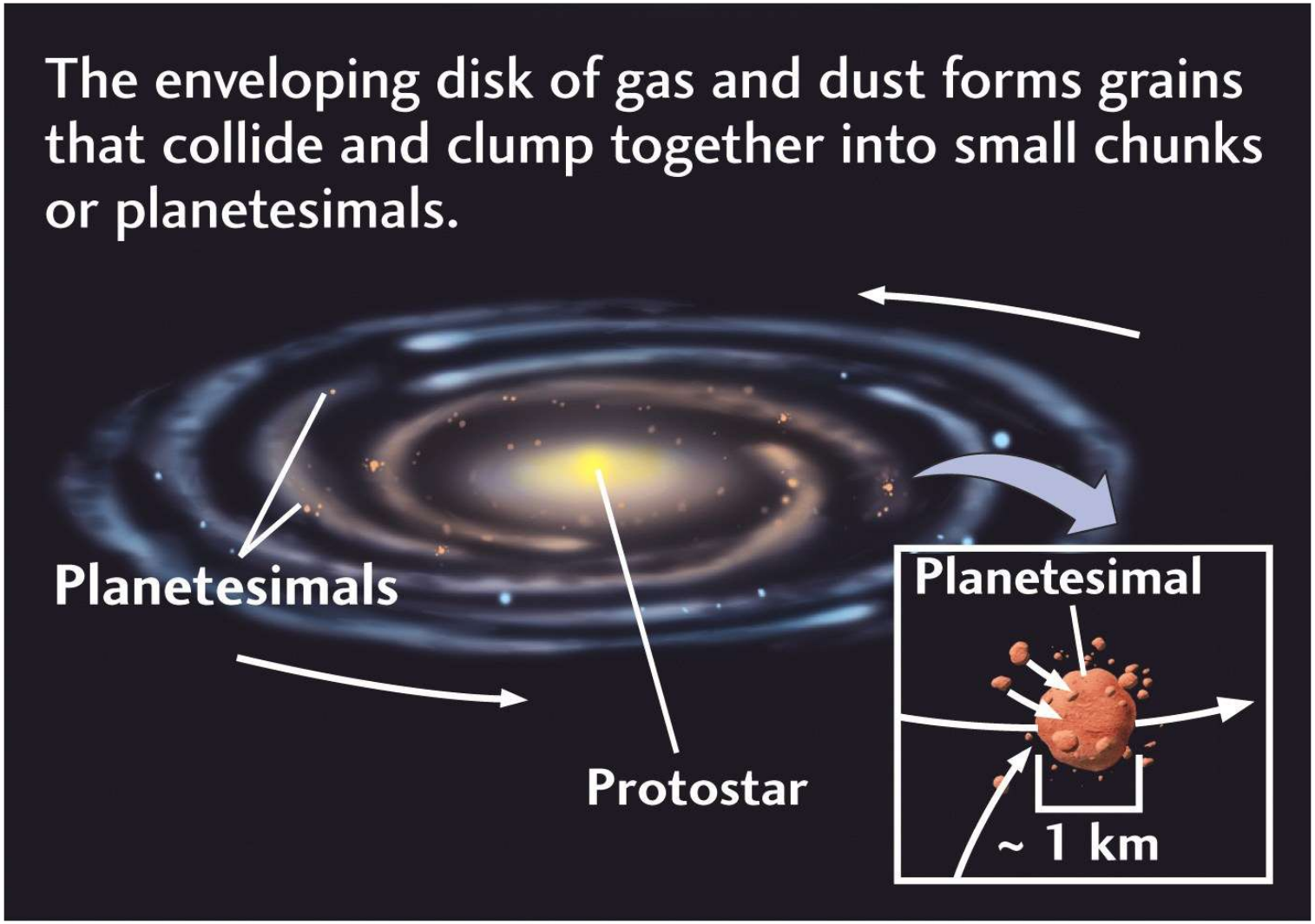
After sufficient mass and density was achieved in the Sun, the temperature rose to ten million °C, resulting in thermonuclear fusion.

H atom + H atom = He atom + energy

Hydrogen atom + hydrogen atom → helium atom + energy



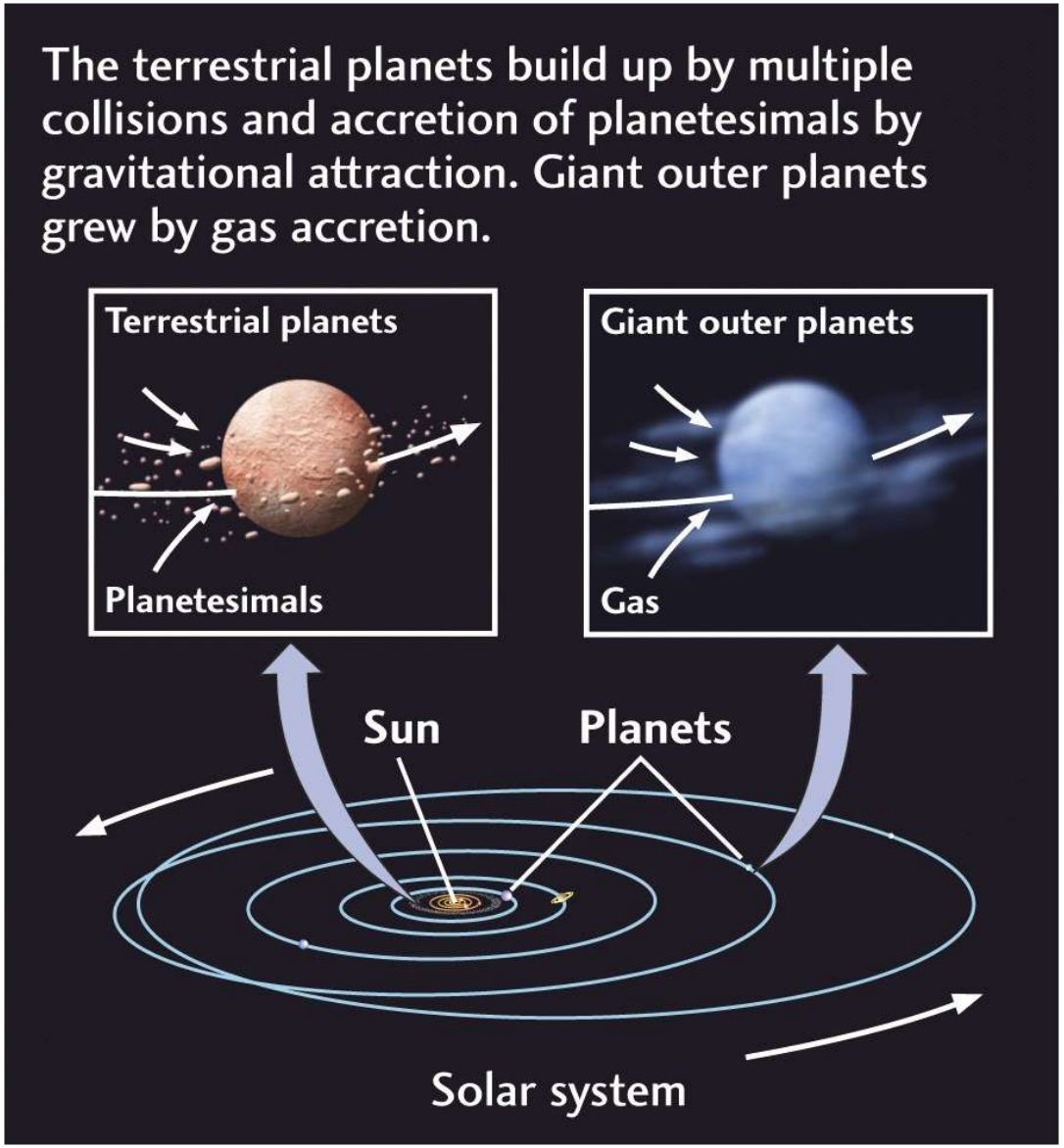
Birth of the Solar System



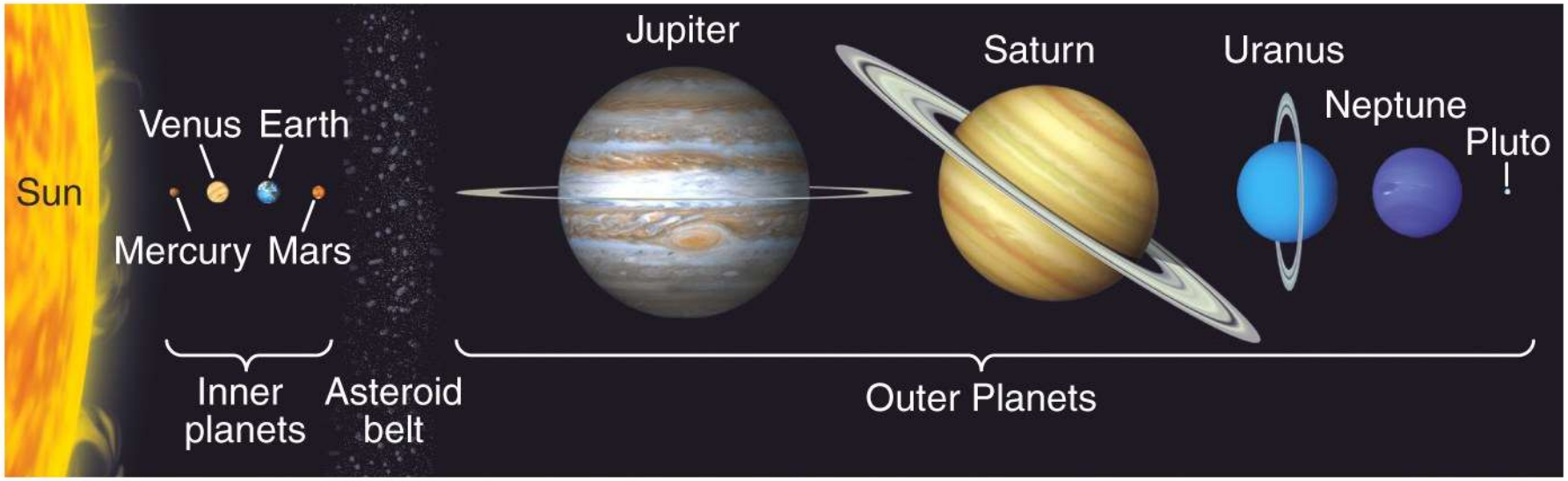
Protoplanets

- Gravitational forces allow the inner planets to accrue (collect) and compact (squish) solid matter
- Solar radiation blew gases (primarily hydrogen, helium) away from inner planets
- These gases were collected and condensed into the gas giants (Jupiter, Saturn, Uranus, Neptune)
- Beyond Neptune, ice and frozen gases form Pluto, Sedna and the Kuiper Belt Objects
- Left-over debris form comets and asteroids

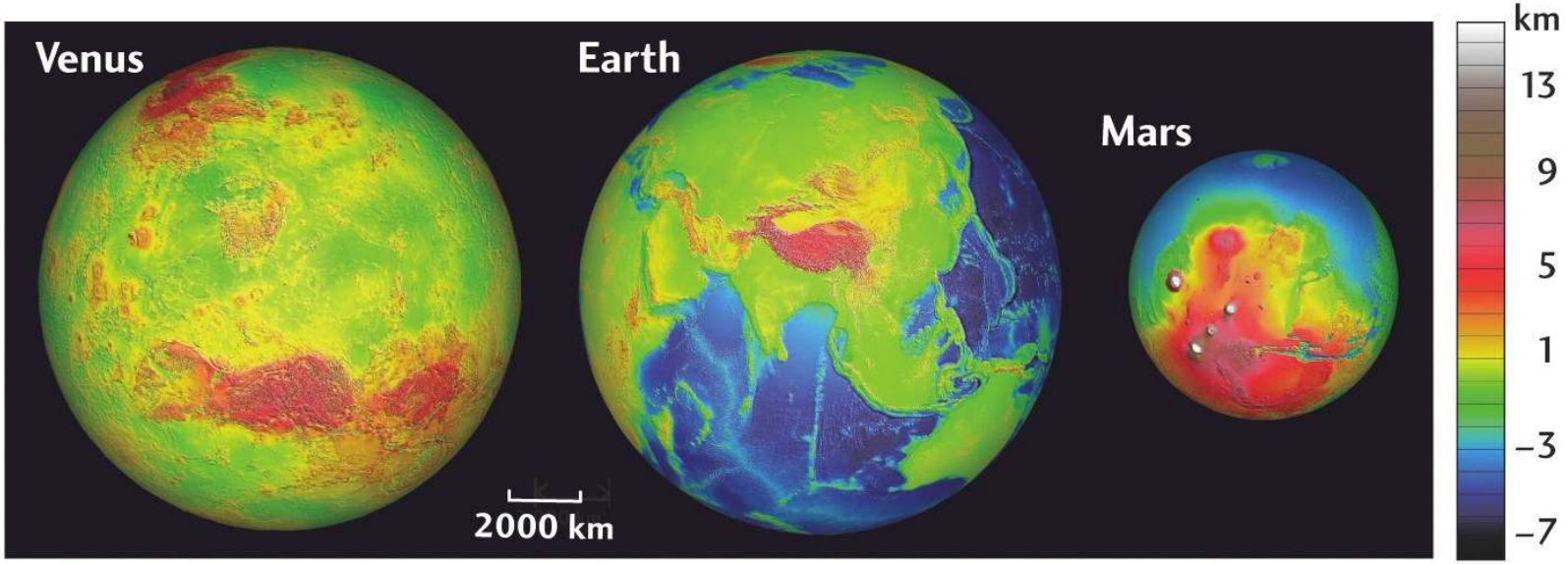
Birth of the Solar System



Size of the Planets



Venus, Earth and Mars



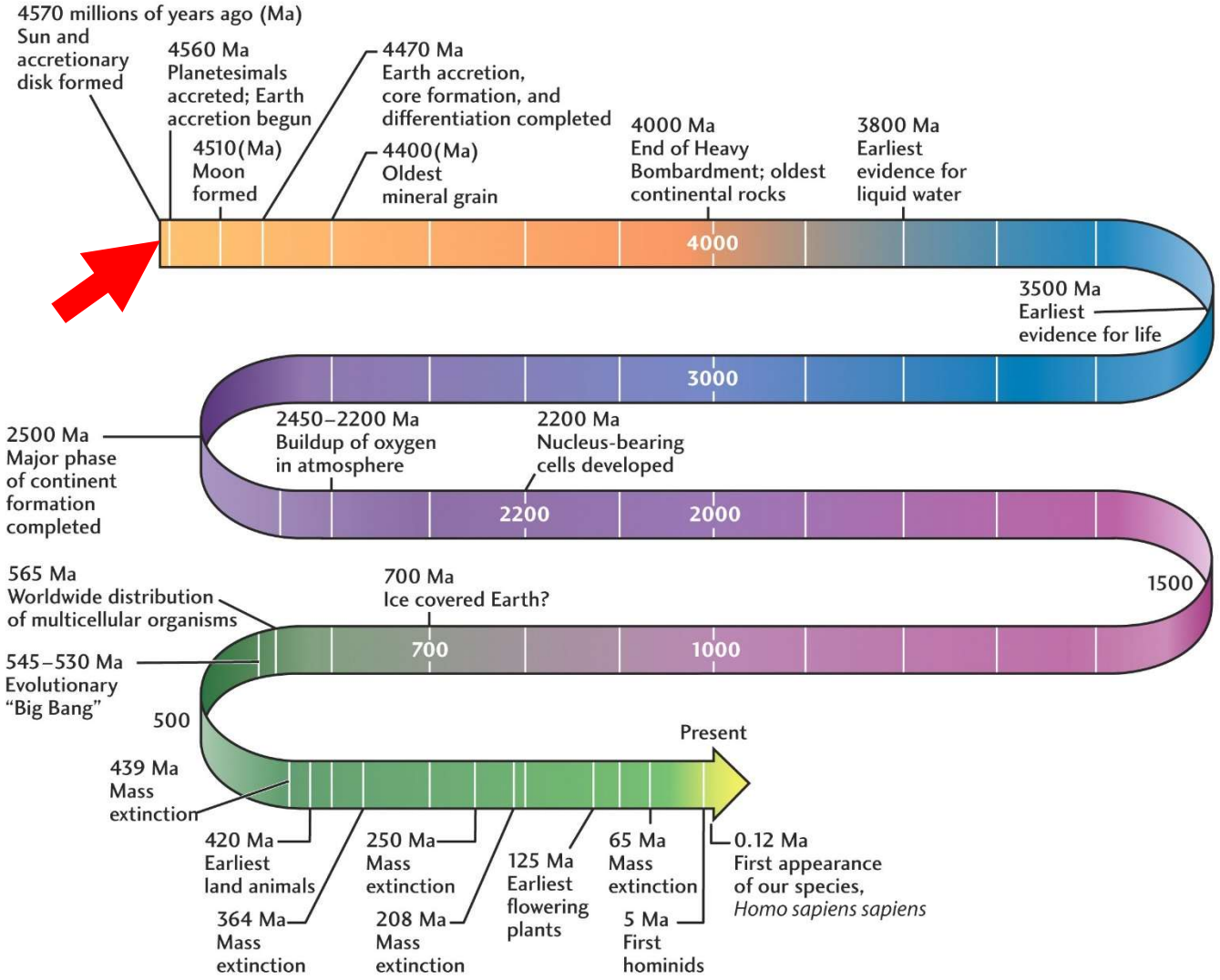
These maps are color coded to display different elevations on the surface of each planet

The Age of the Earth

Earth is ~ 4,570,000,000 years old

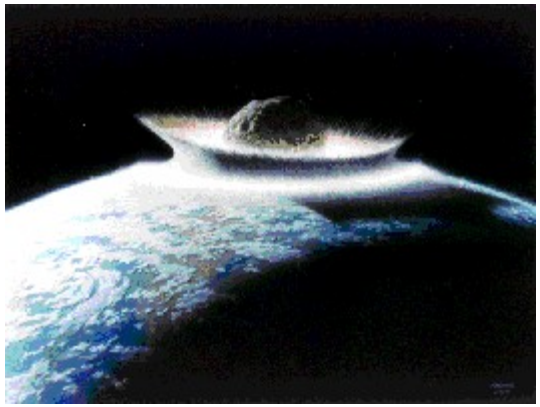
Meteorites give us access to debris left over from the formation of the solar system
We can date meteorites using radioactive isotopes and their decay products

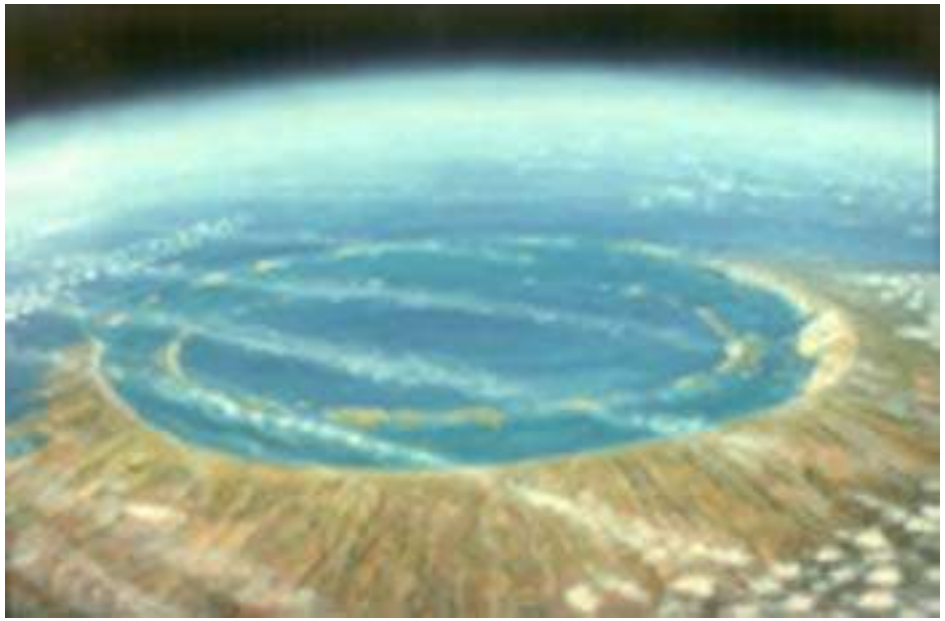
Geologic Time



Bombardment From Space

- For the first half billion years of its existence, the surface of the Earth was repeatedly pulverized by asteroids and comets of all sizes
- One of these collisions formed the Moon



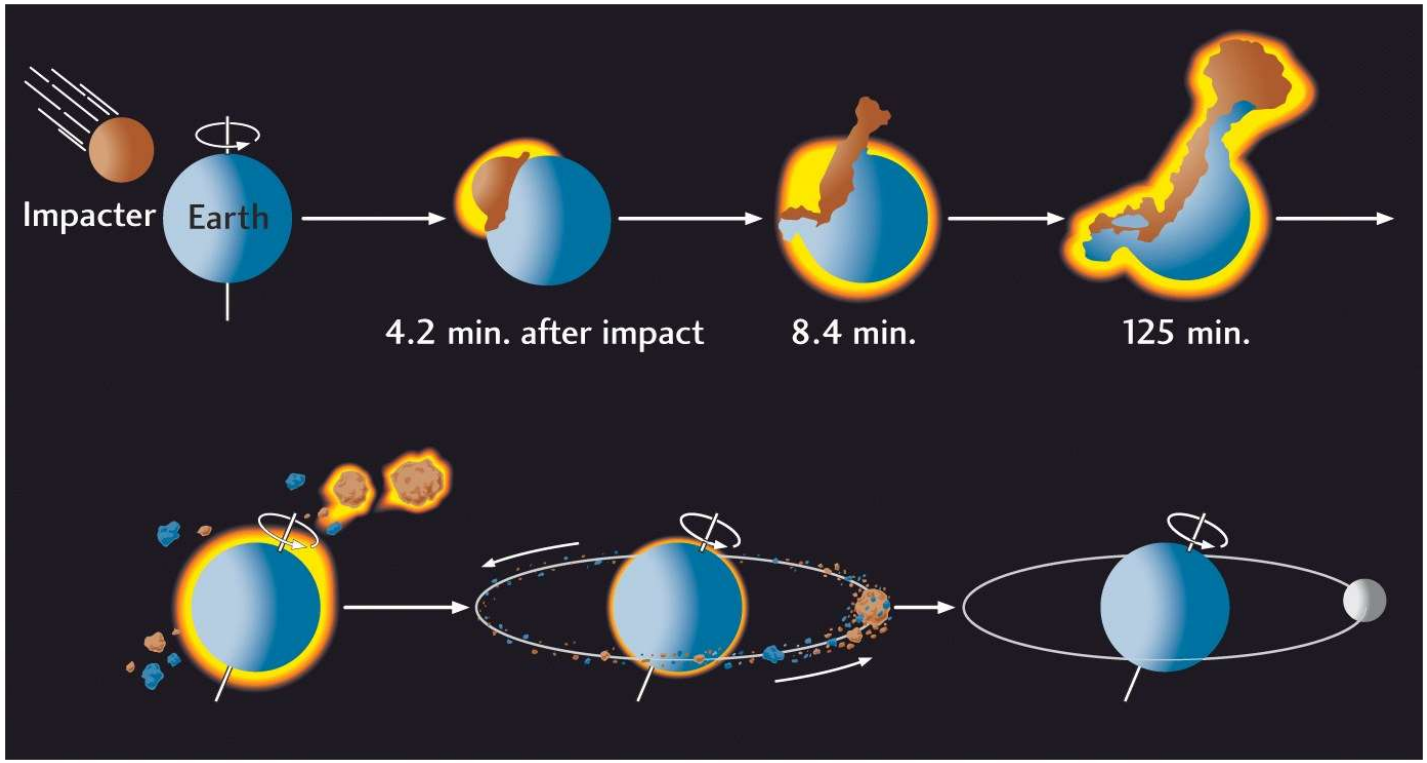


Formation of the Moon

- The **Giant Impact Hypothesis** predicts that around 50 million years after the initial creation of Earth, a planet about the size of Mars collided with Earth
- This idea was first proposed about 30 years ago, but it took calculations by modern high-speed computers to prove the feasibility

Formation of the Moon

- This collision had to be very spectacular!
- A considerable amount of material was blown off into space, but most fell back onto the Earth



Formation of the Moon

- Part of the material from the collision remained in orbit around the Earth
- By the process collision and accretion, this orbiting material coalesced into the Moon
- The early Moon orbited very close to the Earth (15 x closer than today)

Creating the Oceans

It is hypothesized that water vapor escaping from the interior of the Earth via countless volcanic eruptions created the oceans (this took hundreds of millions of years)

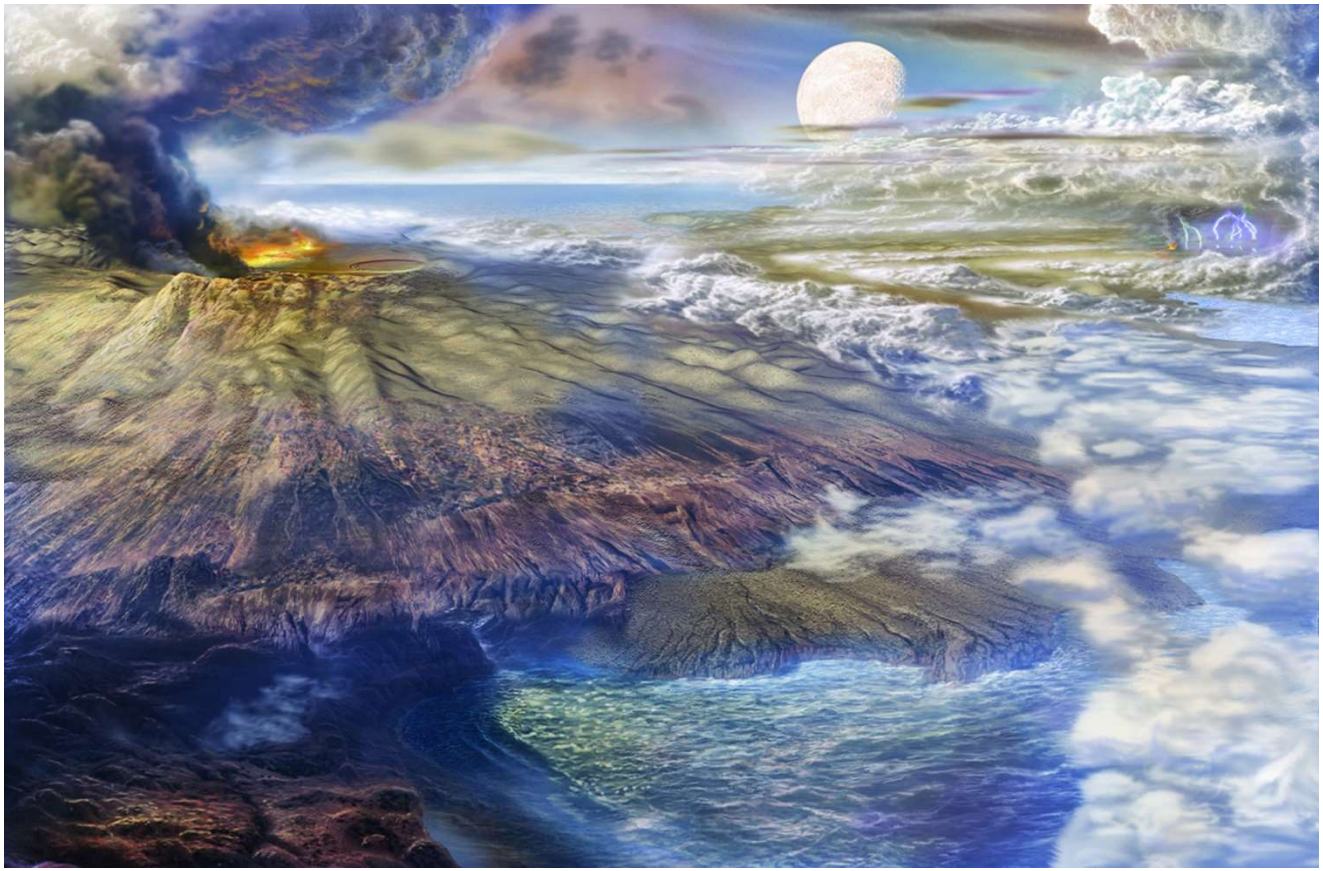
Creating the Oceans

Astronomers also hypothesize that comets impacting the Earth were a major source of water that contributed to creation of the oceans

Remember, that comets are best described as “dirty ice balls”

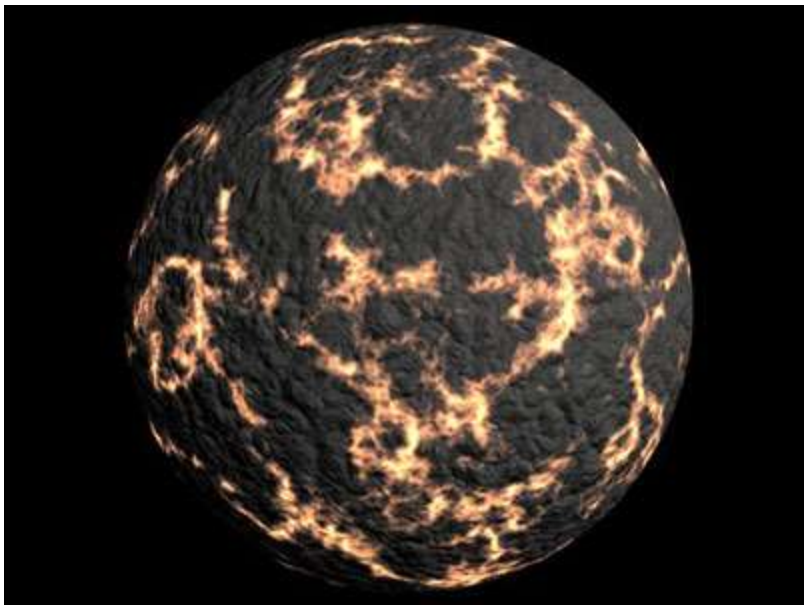
Creating the Oceans

The earliest evidence of surface water on Earth dates back about 3.8 billion years



The Early Earth Heats Up

Three major factors that caused heating and melting in the early Earth's interior:

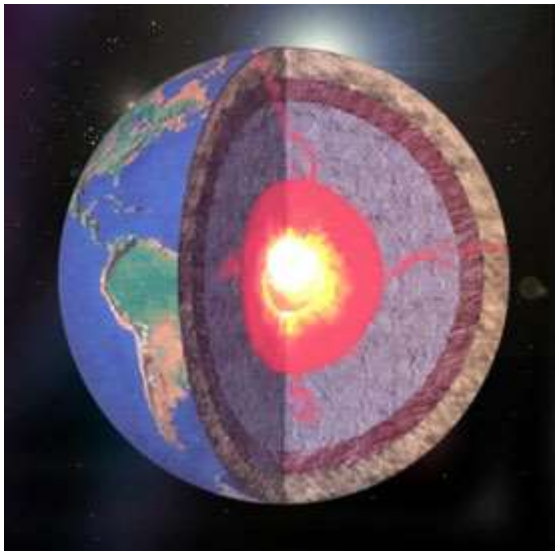


1. **Collisions (Transfer of kinetic energy into heat)**
2. **Compression**
3. **Radioactivity of elements (e.g. uranium, potassium, or thorium)**

The Core

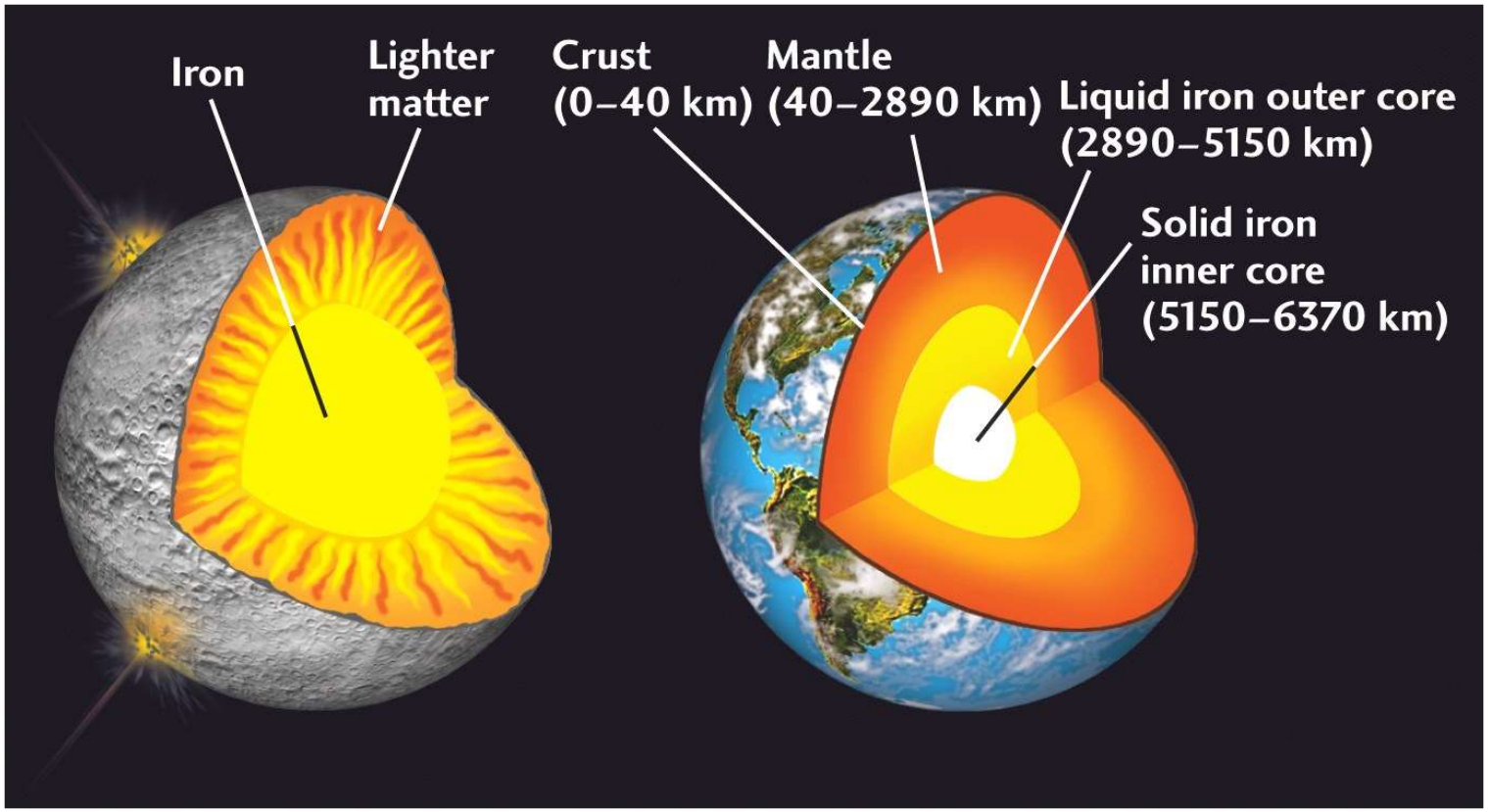
About 100 million years after initial accretion, temperatures at depths of 400 to 800 km below the Earth's surface reach the melting point of iron

In a process called global chemical differential, the heavier elements, including the melted iron, began to sink down into the core of the Earth, while the lighter elements such as oxygen and silica floated up towards the surface



Global Chemical Differentiation

This global chemical differential was completed by about 4.3 billion years ago, and the Earth had developed a inner and outer core, a mantle and crust

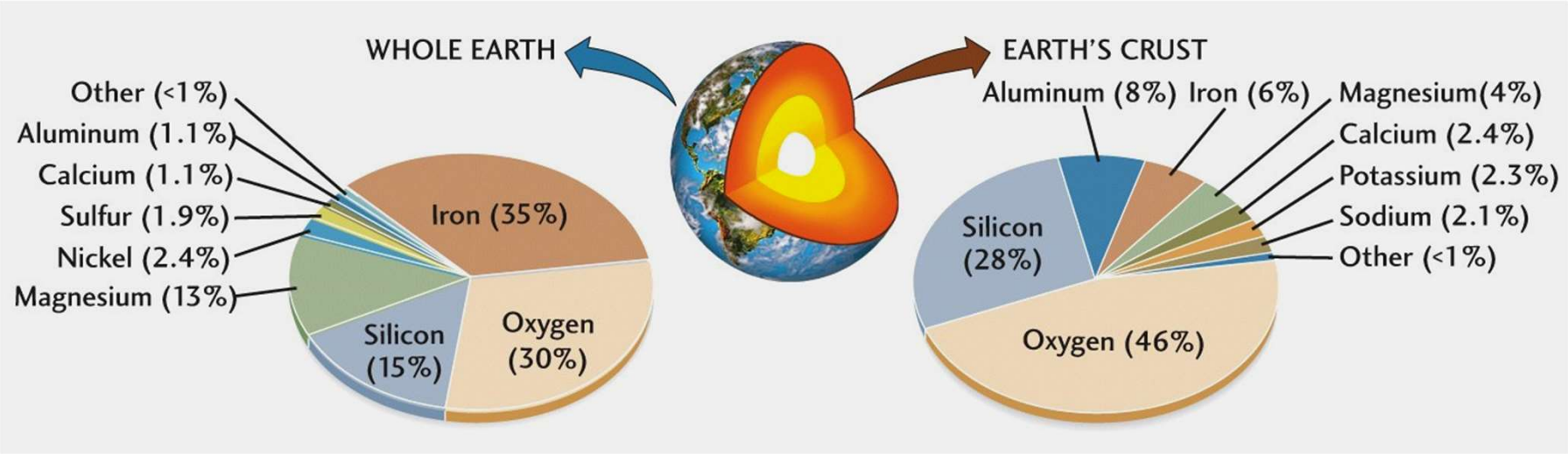


Chemical Composition of Earth

Each of the major layers has a distinctive chemical composition, with the crust being quite different from the Earth as a whole

Whole Earth:
Fe+O+Si+Mg = 93%

Crust:
Si+O+Al = 82%



Chemical Composition of Earth

Lithosphere: strong, rocky outer shell of the solid Earth including all the crust and the upper part of the mantle to a depth of ~100 km (forms the plates)

Asthenosphere: weak,ductile layer of the mantle beneath the lithosphere; deforms to accommodate the motions of the overlying plates

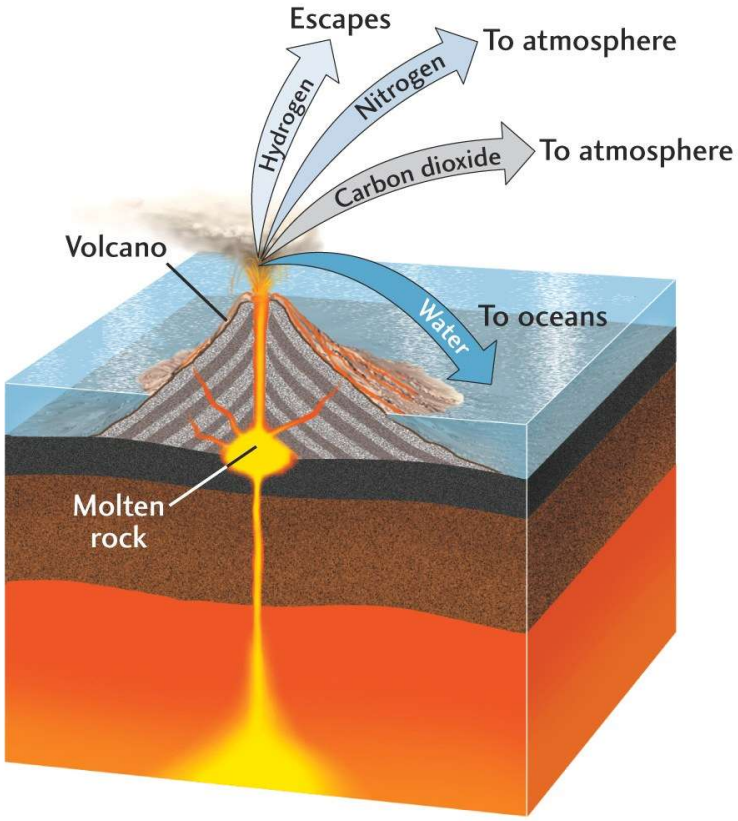
Deep Mantle: mantle beneath the asthenosphere (~400 to 2900 km in depth)

Outer core: liquid shell composed of mostly iron

Inner core: innermost sphere composed primarily of solid iron

Chemical Composition of Earth

Continents: Formed from solidified magma that floated up from the Mantle



Oceans and Atmosphere: Fluid and gaseous outer layers believed to have been created by out-gassing of gases and fluids from volcanic eruptions (in a process called **volatile transfer**)

The Evolving Atmosphere

Right after its creation, the Earth is thought to have had a thin atmosphere composed primarily of helium (He) and hydrogen (H) gases

The Earths gravity could not hold these light gases and they easily escaped into outer space

Today, H and He are very rare in our atmosphere

The Evolving Atmosphere

For the next several hundred million years, volcanic out-gassing began to create a thicker atmosphere composed of a wide variety of gases

The gases that were released 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)

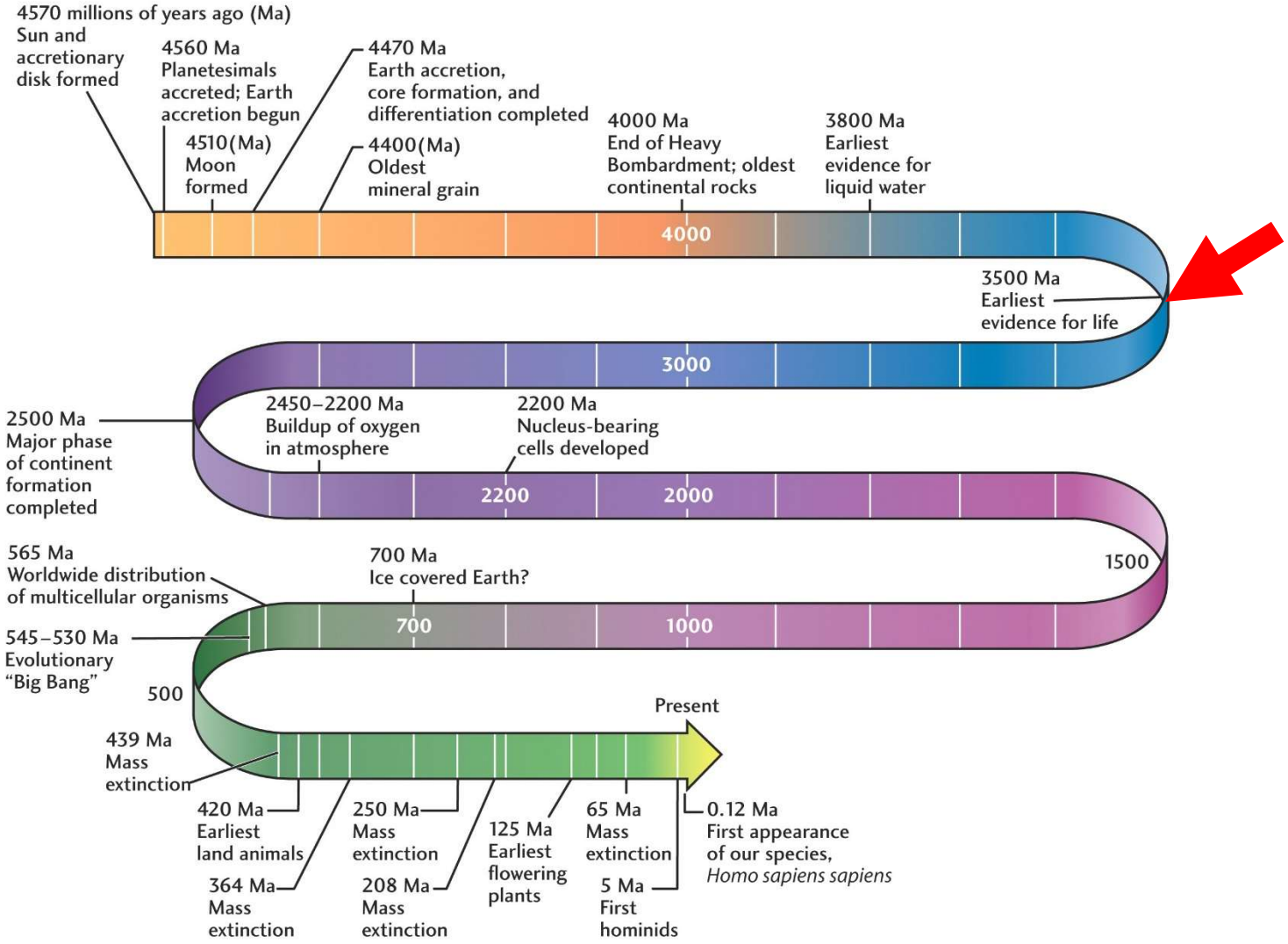
Carbon Monoxide (CO)

Ammonia (NH_3)

Methane (CH_4)

Note that oxygen (O2) gas is not created by volcanic eruptions

Geologic Time



A billion Year Old Earth

By 3.5 billion years ago, when the Earth was a billion years old, it had a thick atmosphere composed of CO_2, methane, water vapor and other volcanic gases

By human standards this early atmosphere was very poisonous

It contained almost no oxygen

Remember, today our atmosphere is 21% oxygen

A billion Year Old Earth

By 3.5 billion years ago, the Earth also had extensive oceans and seas of salt water, which contained many dissolved elements, such as iron

A billion Year Old Earth

But most important, by 3.5 billion years ago, there was life on Earth

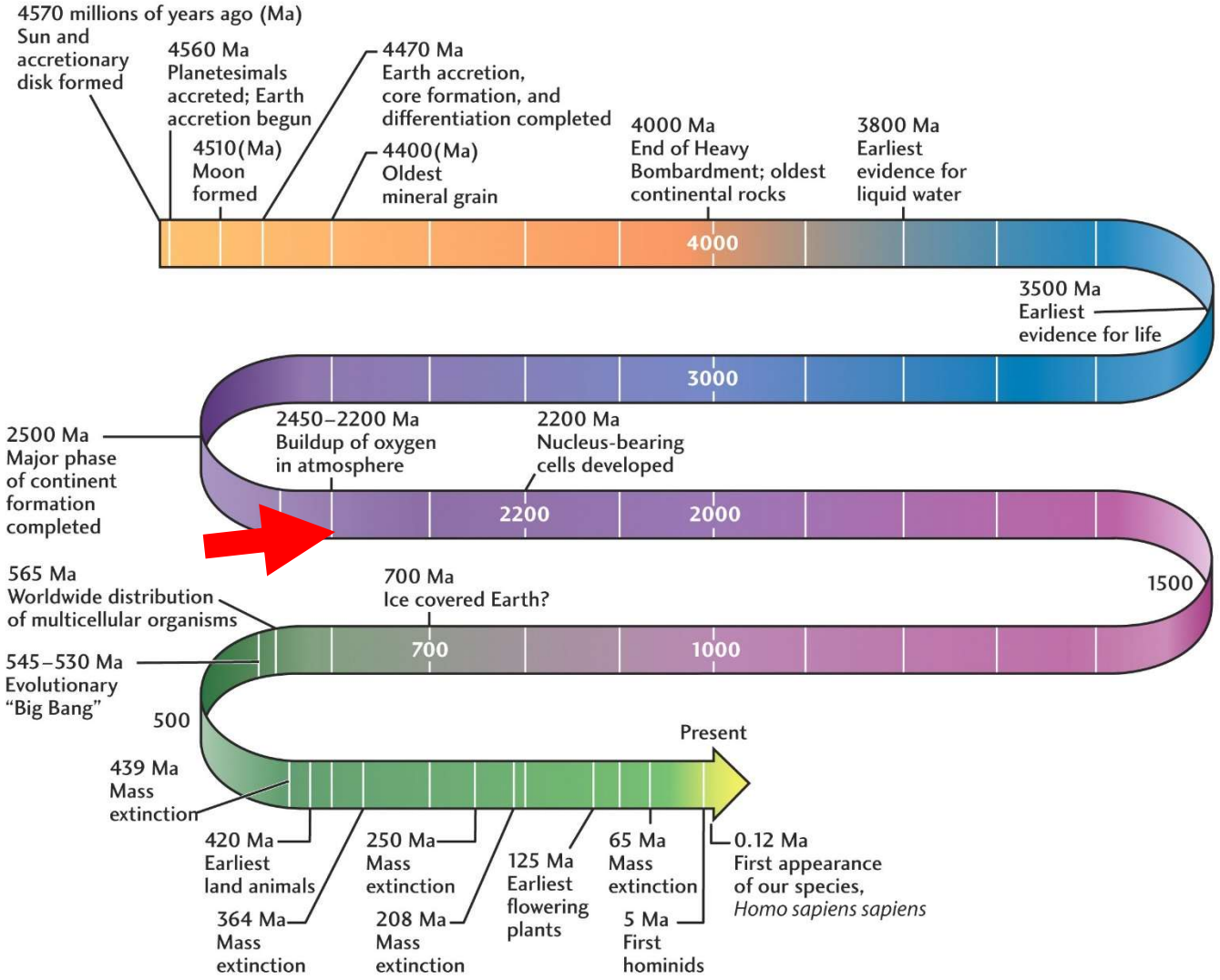
The Continents

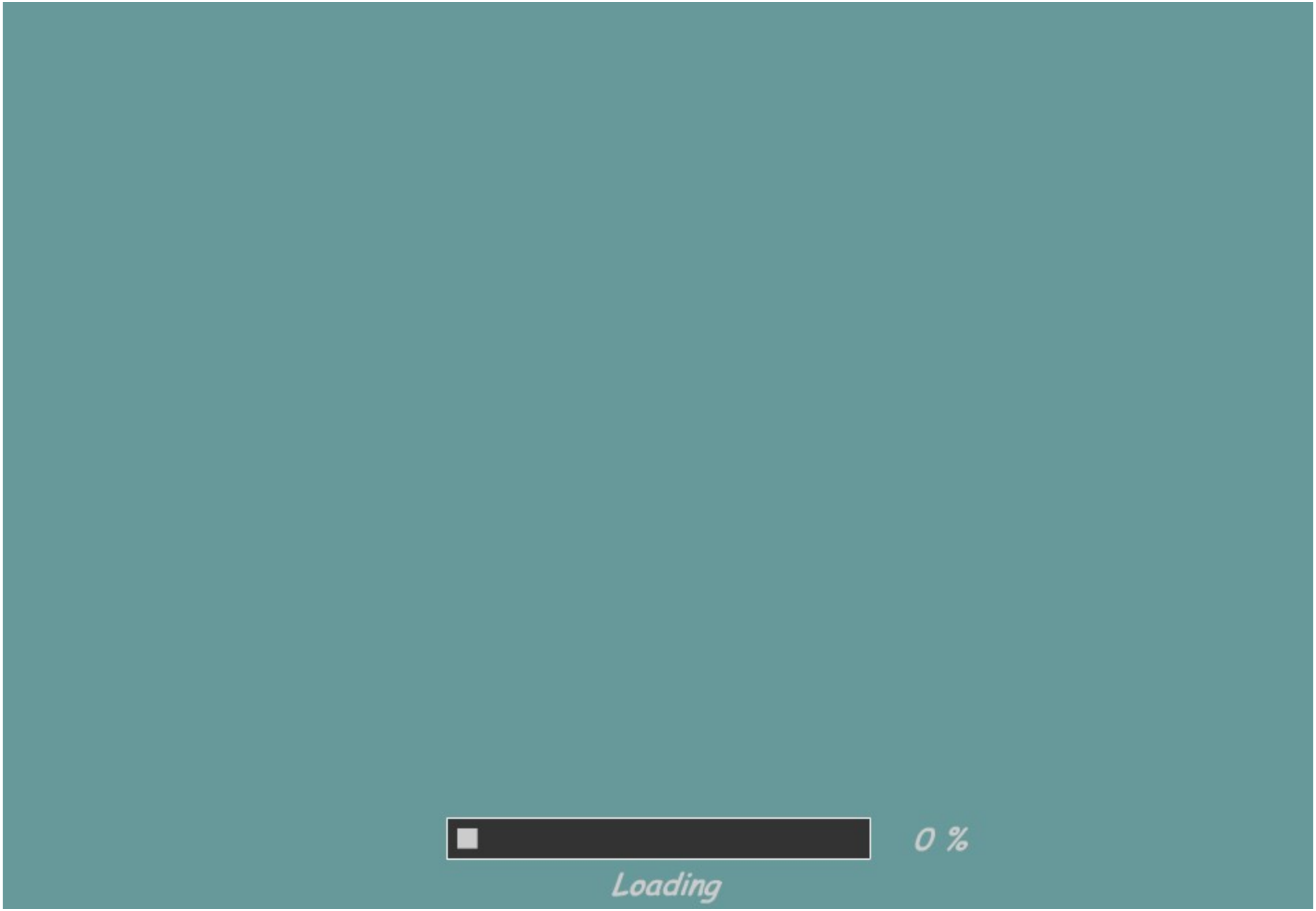
By 2.5 billion years ago, the continents had been formed

The density of the continental crust (2.8 gr/cm^3) is lighter that the crust found on ocean bottoms (3.2 gr/cm^3), so the continents rise above the ocean floor

A question that remains unanswered is, when did plate tectonics start?

Geologic Time

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