The Earth System

Connections among the great spheres

Objectives

At the completion of this material, the student will be able to;

Understand the Earth system relative to its surroundings

Know the spheres that make up Earth’s system, what they include, and how they interact with each other

This Island Earth

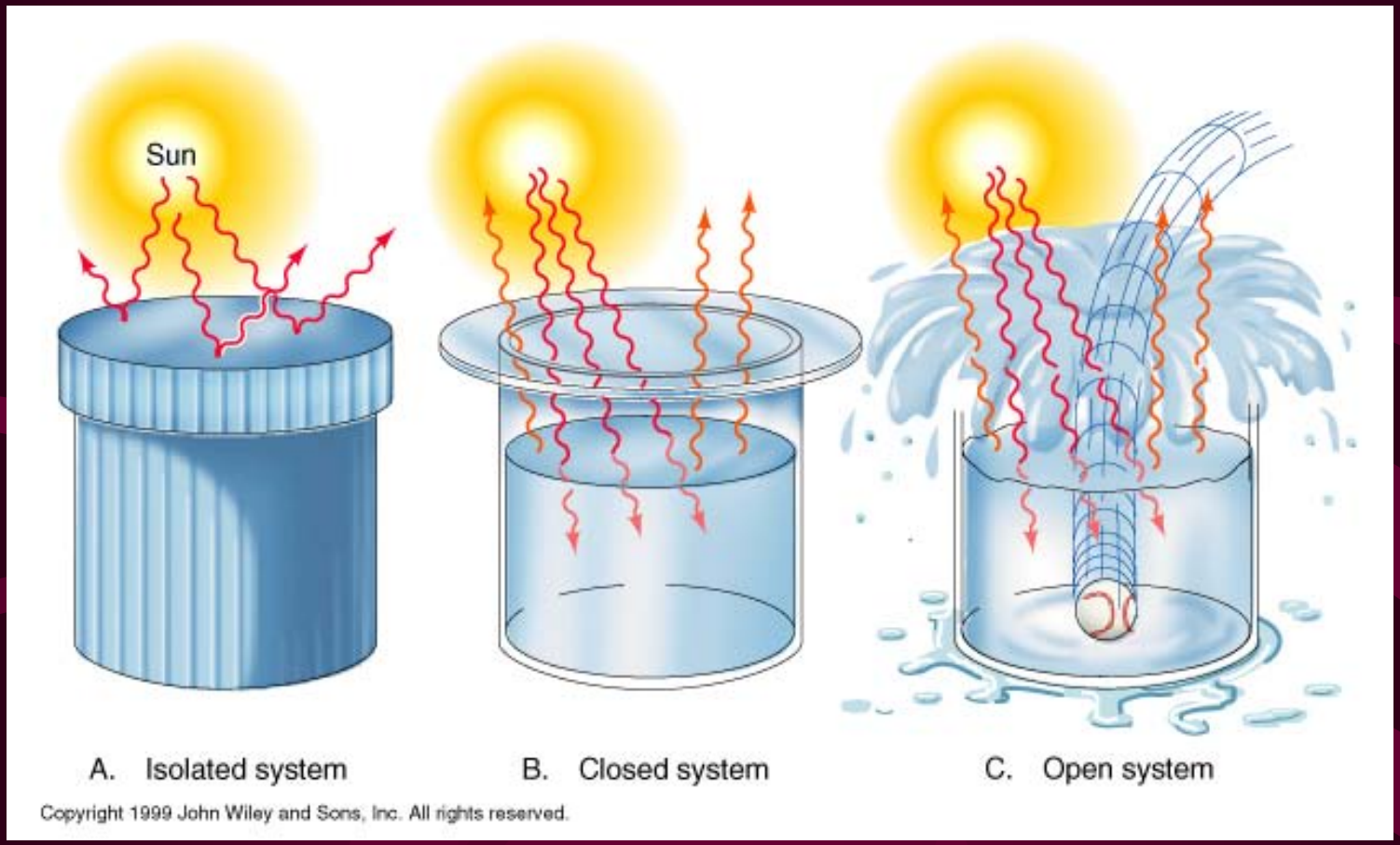
About 4.5 billion years old

Geologically dynamic internally and externally

Only planet presently known to support life

As far as life is concerned: “Goldilocks of the Solar System” (relative to Sun, not too far, not too close, just right !)

Earth As A Closed System



Closed system: exchange of energy but negligible exchange of mass with surroundings

Earth’s Four Spheres

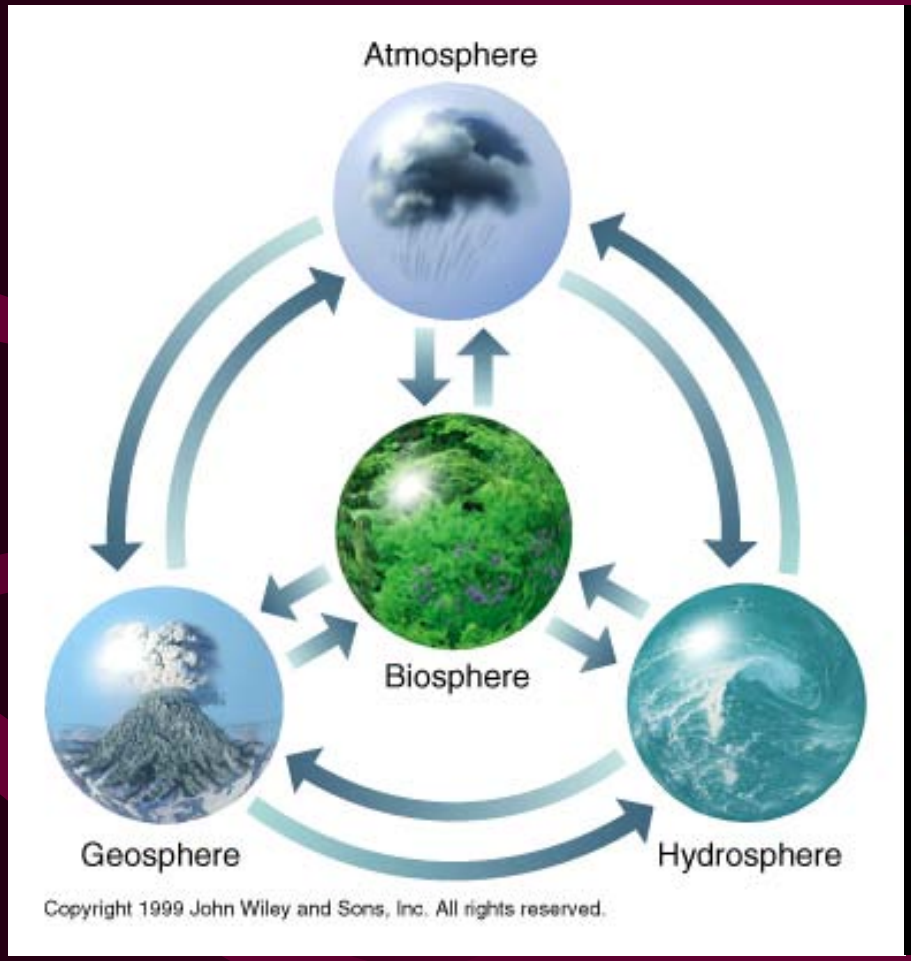
Geosphere: comprises the solid Earth and includes both Earth’s surface and the various layers of the Earth's interior.

Atmosphere: gaseous envelope that surrounds the Earth and constitutes the transition between its surface and the vacuum of space

Hydrosphere: includes all water on Earth (including surface water and groundwater)

Biosphere: the life zone of the Earth and includes all living organisms, and all organic matter that has not yet decomposed.

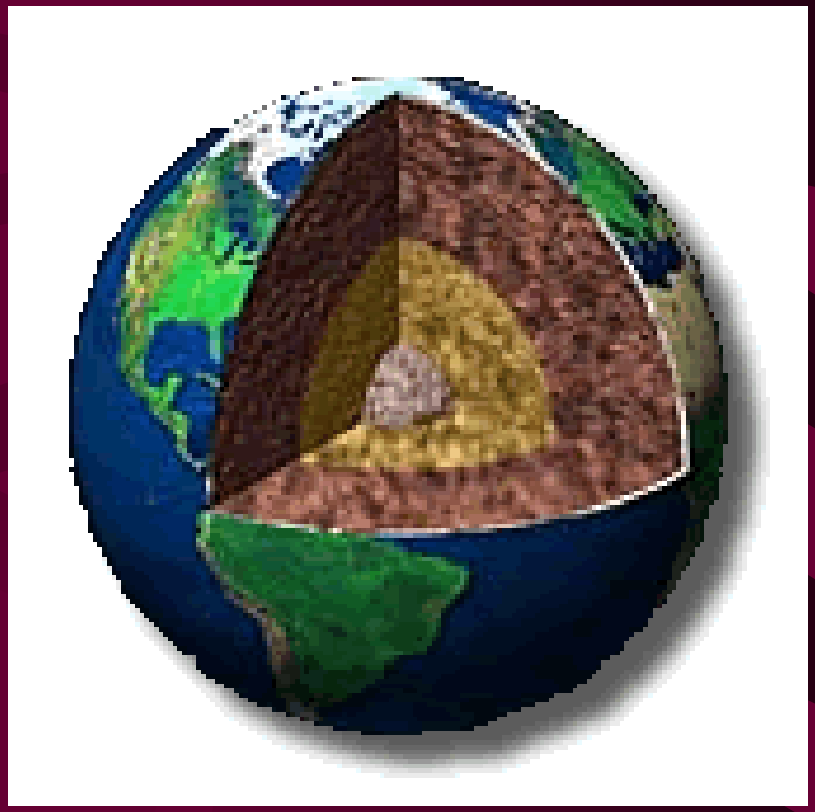
The Earth's Four Spheres



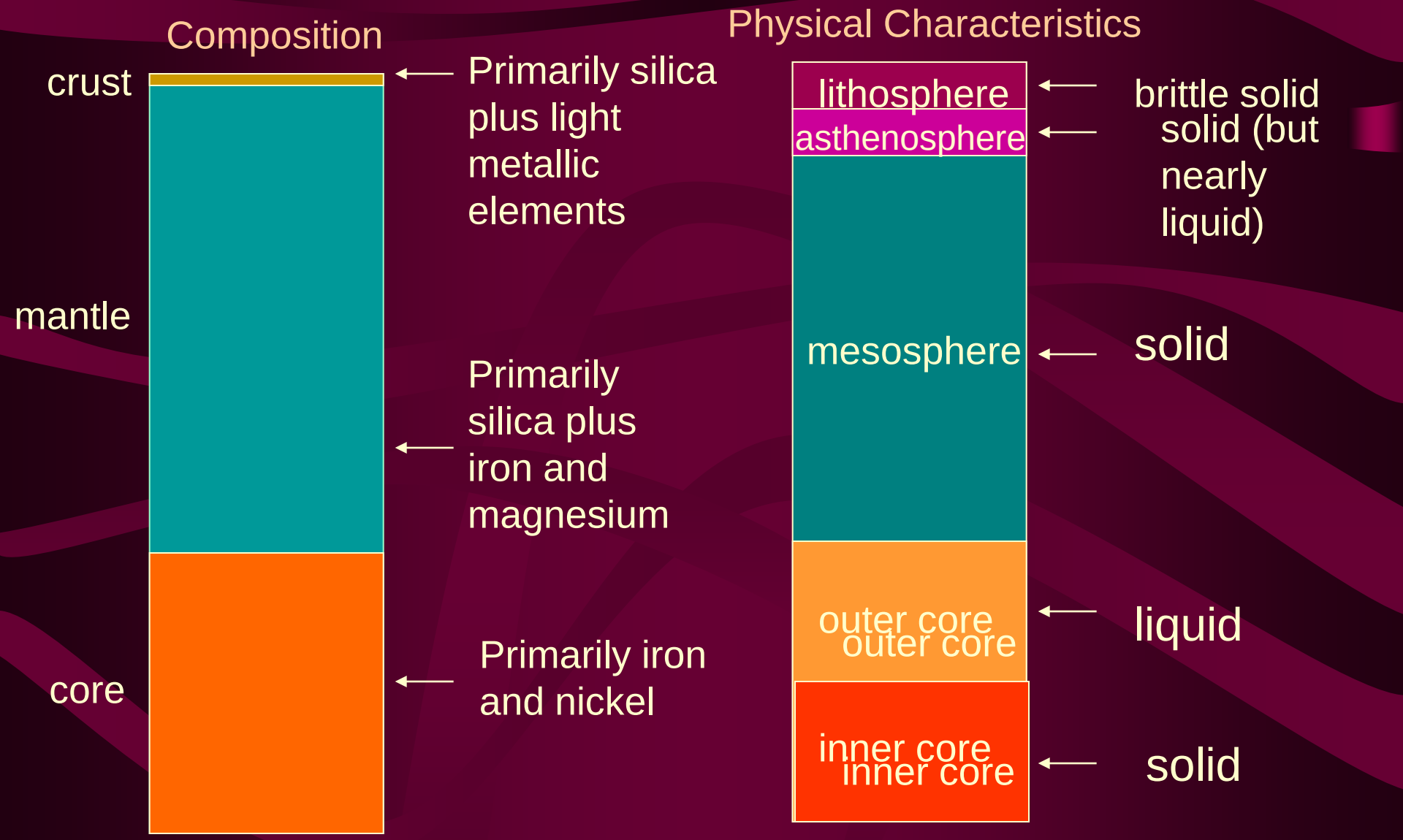
Geosphere (Solid Earth)

- 94 % percent of the earth is composed of the elements oxygen and silicon (combined as the compound silica [silicon oxide: SiO_2]), iron and magnesium

- interior of the earth is layered both chemically and mechanically.

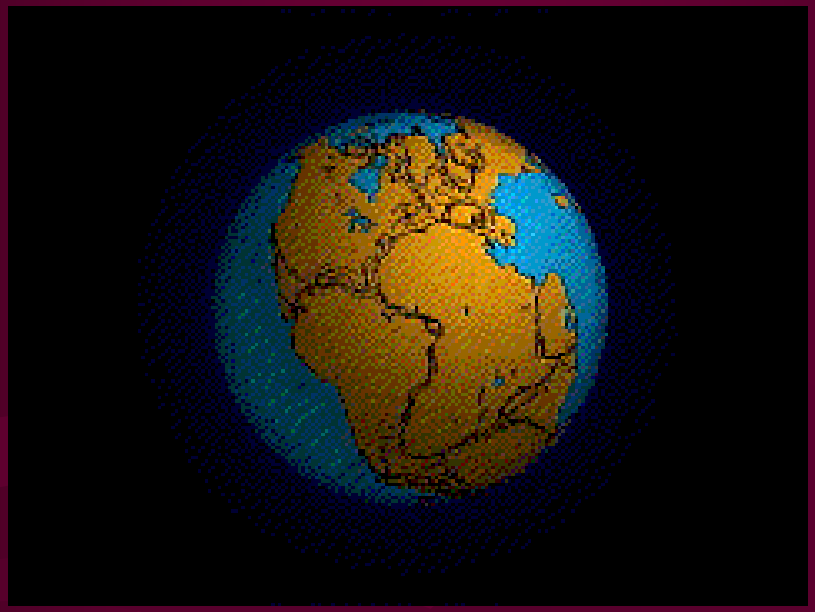


Earth's Layers: Composition and Mechanical Characteristics



Note: Lithosphere contains both crust and uppermost (brittle) layer of mantle

The dynamic geosphere



Earth 200 million years ago to present

The geosphere is not static. Due to movement of material within Earth, the lithosphere (Earth's brittle outer shell) is broken into plates that are in a constant state of motion (plate tectonics).

The movement of plates is indicated by continental drift.

Geosphere: Interactions with other Earth System components

Atmosphere: volcanism spews significant amounts of gases into the atmosphere. For example, volcanoes inject large amounts of sulphur dioxide to the upper atmosphere, resulting in global cooling.

Hydrosphere: The formation of many minerals involve incorporation or release of water. Also, water speeds up chemical reactions that produce or destroy minerals, and aids in the melting of rock.

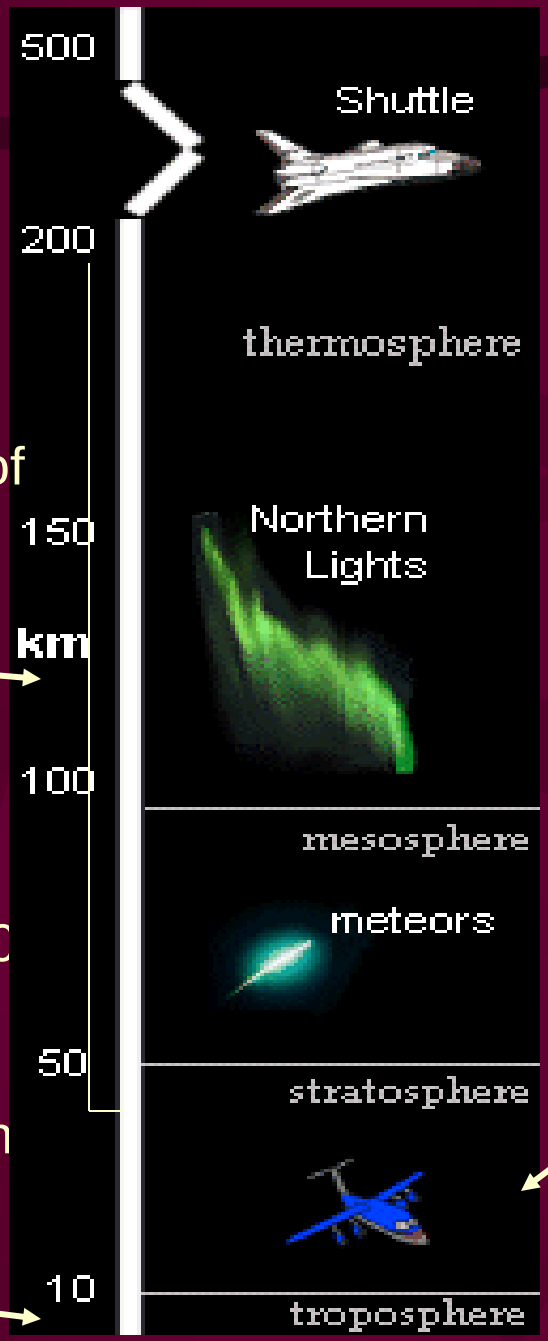
Biosphere: Nutrients released from rocks during their breakdown are dissolved in water (to be used by aquatic plants).

Atmosphere

• consists of a mixture of gases composed primarily of nitrogen, oxygen, carbon dioxide, and water vapour

•The mesosphere, thermosphere, and exosphere are zones of diffuse atmospheric components in the far reaches of the atmosphere.

•The troposphere (0-10 km) constitutes the climate system that maintains the condition suitable for life on the planet's surface.



The stratosphere (10 to 50 km), contains ozone that protects life on the planet by filtering harmful ultraviolet radiation from the Sun.

Atmosphere: Interactions with other Earth System components

Hydrosphere: The gases of the atmosphere readily exchange with those dissolved in water bodies (e.g. oceans, lakes, etc.)

Biosphere: The atmosphere supplies oxygen and carbon dioxide that form the basis of life processes (photosynthesis and respiration).

Geosphere: Gases in the atmosphere react with water to produce weak acids that aid in the breakdown of rock.

Hydrosphere

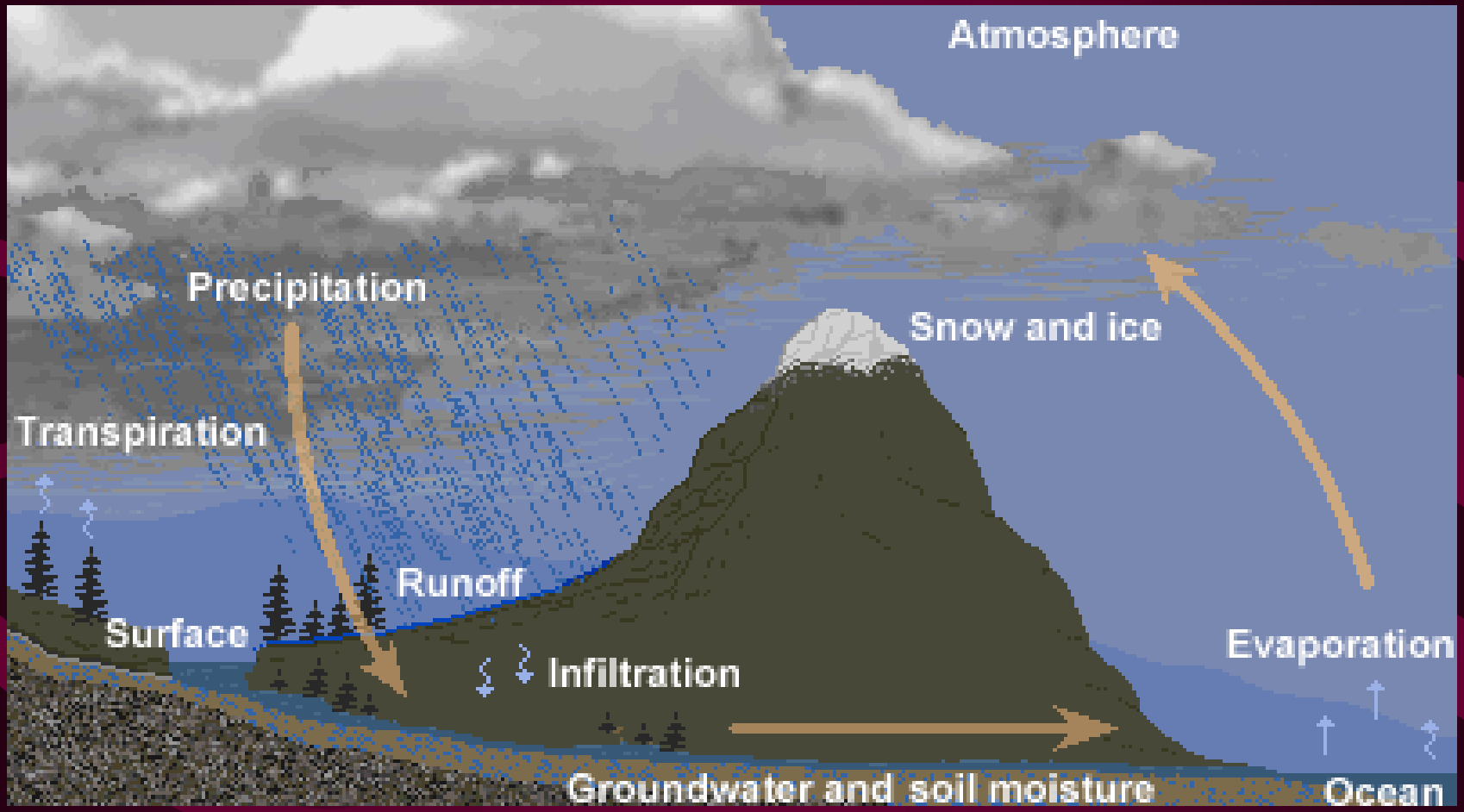
• abundance of liquid water on Earth makes it distinct from other bodies in the solar system (71% of the earth covered by water)

• it is because the Earth has just the right mass, the right chemical composition, the right atmosphere, and is the right distance from the Sun (the "Goldilocks" principle) that permits water to exist mainly as a liquid.

• range of surface temperatures and pressures of our planet permit water to exist in all three states: solid (ice), liquid (water), and gas (water vapour).

• even so, most of the water is contained in the oceans and the high heat capacity of this large volume of water buffers the Earth surface from large temperature changes

Subcomponents of hydrosphere are connected via the hydrologic cycle



Hydrosphere: Interactions with other Earth System components

Atmosphere: Water is transferred between the hydrosphere and biosphere by evaporation and precipitation. Energy is also exchanged in this process.

Biosphere: Water is necessary for the transport of nutrients and waste products in organisms.

Geosphere: Water is the primary agent for the chemical and mechanical breakdown of rock (weathering), to form loose rock fragments and soil, and sculpts the surface of the Earth.

Biosphere

• Life evolved on earth during its early history by at least 3.5 billion years ago and the biosphere readily distinguishes our planet from all others in the solar system (as far as we know)

•The chemical reactions of life (e.g., photosynthesis-respiration, precipitation of minerals in skeletons, etc.) have also imparted a strong signal on the chemical composition of the atmosphere through time. For example, our oxygen-rich atmosphere is largely a product of photosynthesis.

Biosphere: Interactions with other Earth System components

Atmosphere: Life processes involve a many chemical reactions which either extract or emit gases to and from the atmosphere (e.g. photosynthesis consumes carbon dioxide and releases oxygen, whereas respiration does the opposite).

Hydrosphere: Evaporation of water from leaf surfaces (transpiration) transfers water to the atmosphere.

Geosphere: The biosphere is connected to the geosphere through soils (mixtures of air, mineral matter, organic matter, and water). Plant activity (e.g. root growth and organic acid production) are also for the mechanical and chemical breakdown of the rocks.

Just how integrated is the Earth System ?

James Lovelock (1979) introduced a somewhat extreme concept called the Gaia Hypothesis

Proposed that Earth functions as a single superorganism that maintains conditions necessary for its survival.

Inherent in explanation is the idea that the biosphere, atmosphere, geosphere and hydrosphere are in a delicate balance – that a homeostatic condition is maintained

Analogous to how processes within the human body insure that temperature, blood pH, electrochemistry, etc. are kept in balance for our survival.

In an extreme sense, the inner workings of Gaia could be viewed as a study of the physiology of the Earth where water is the Earth's "blood," the atmosphere is the Earth's lungs, the geosphere is the Earth's "solid tissues," and living organisms are the Earth's "senses"…um…yeah, whatever.

BUT…

…while Earth is probably not a sentient being as Lovelock implies, the Gaia Hypothesis does underscore the importance of looking at Earth processes as interconnected parts of a larger system

As a closed system, Earth’s processes adjust to disturbances in the system to maintain balance

The Bottom Line

Considerations on how processes within the Earth System interact are extremely important in the understanding of the real world !

Understanding physical and chemical processes in the Earth System is as important as understanding biological entities in terms of understanding biological systems (all are connected)

END OF LECTURE