Chapter 3
The Dynamic Earth
Section 1: The Geosphere

DAY 1
The Dynamic Earth

Section 1

The Earth as a System

- The Earth is an integrated system that consists of **rock, air, water, and living things** that all interact with each other.

- Scientists divided this system into four parts:
  - The Geosphere (rock)
  - The Atmosphere (air)
  - The Hydrosphere (water)
  - The Biosphere (living things)
The Dynamic Earth

Section 1

The Earth as a System
The Dynamic Earth

Section 1

The Earth as a System

• The **geosphere** is the mostly solid, rocky part of the Earth that extends from the center of the core to the surface of the crust.

• The atmosphere is the mixture of gases that makes up the air we breathe.

• Nearly all of these gases are found in the first **30 km** above the Earth’s surface.
The Earth as a System

- The hydrosphere makes up all of the **water on or near the Earth’s surface**.
- Much of this water is in the **oceans**, which cover nearly three-quarters of the globe.
- However, water is also found in the atmosphere, on land, and in the soil.
The Earth as a System

- The **biosphere** is the part of the Earth where life exists.

- It is a thin layer at the Earth’s surface that extends from about **9 km** above the Earth’s surface down to the bottom of the ocean.

- The biosphere is therefore made up of parts of the geosphere, the atmosphere, and the hydrosphere.
Discovering Earth’s Interior

- Scientists use **seismic waves** to learn about Earth’s interior.
- Seismic waves are the same waves that travel through Earth’s interior during an earthquake.
- A similar process would be you tapping on a melon to see if it is ripe.
Discovering Earth’s Interior

- A seismic wave is **altered by the nature of the material** through which it travels.

- Seismologists measure changes in the **speed and direction** of seismic waves that penetrate the interior of the planet.

- With this technique, seismologists have learned that the Earth is made up of different layers and have inferred what substances make up each layer.
Discovering Earth’s Interior

Seismic waves change both speed and direction as they pass from one physical layer to another.

Earthquakes produce seismic waves that travel at different speeds through the different layers of the Earth.
The Composition of the Earth

- Scientists divide the Earth into three layers:
  - The crust
  - The mantle
  - The core
- These layers are made up of progressively denser material toward the center of the Earth.
The Composition of the Earth

- **The crust** is the thin and solid outermost layer of the Earth above the mantle.
- It is the **thinnest layer**, and makes up less than **1 percent** of the planet’s mass.
- It is **5 km to 8 km thick** beneath the oceans and is **20 km to 70 km thick** beneath the continents.
The Composition of the Earth

- The **mantle** is the layer of rock between the Earth’s crust and core.
- The mantle is made of rocks of medium density, and makes up 64 percent of the mass of the Earth.
- The **core** is the central part of the Earth below the mantle, and is composed of the densest elements.
The Structure of the Earth

- The Earth can be divided into five layers based on the physical properties of each layer.

- The **lithosphere** is the solid, outer layer of the Earth that consists of the crust and the rigid upper part of the mantle.

- It is a cool, rigid layer that is 15 km to 300 km thick and is divided into huge pieces called **tectonic plates**.
The Structure of the Earth

- The **asthenosphere** is the solid, plastic layer of the mantle beneath the lithosphere.
- It is made of **mantle rock** that flows slowly, which allows tectonic plates to move on top of it.
- Beneath the asthenosphere is the **mesosphere**, the lower part of the mantle.
The Structure of the Earth

• The Earth’s **outer core** is a dense liquid layer.

• At the center of the Earth is a dense, solid inner core, which is made up mostly of **iron and nickel**.

• Although the temperature of the inner core is estimated to be between 4,000°C to 5,000°C, it is solid because it is under enormous pressure.

• The inner and outer core make up about **one-third** of Earth’s mass.
Earth’s Layers

**Crust**  5–70 km thick; the solid, brittle, outermost layer of the Earth; continental crust is thick and made of lightweight materials, whereas oceanic crust is thin and made of denser materials.

**Mantle**  2,900 km thick; the layer of the Earth between the crust and the core; made of dense, iron-rich minerals.

**Core**  3,428 km radius; a sphere of hot, dense nickel and iron at the center of the Earth.

**Lithosphere**  15–300 km thick; the cool, rigid, outermost layer of the Earth; consists of the crust and the rigid, uppermost part of the mantle; divided into huge pieces called tectonic plates, which move around on top of the asthenosphere and can have both continental and oceanic crust.

**Asthenoosphere**  250 km thick; the solid, plastic layer of the mantle between the mesosphere and the lithosphere; made of mantle rock that flows very slowly, which allows tectonic plates to move on top of it.

**Mesosphere**  2,550 km thick; the “middle sphere”; the lower layer of the mantle between the asthenosphere and the outer core.

**Outer Core**  2,200 km thick; the outer shell of Earth’s core; made of liquid nickel and iron.

**Inner Core**  1,228 km radius; a sphere of solid nickel and iron at the center of the Earth.
Plate Tectonics

- **Tectonic plates** are blocks of lithosphere that consist of the crust and the rigid, outermost part of the mantle and glide across the underlying asthenosphere.

- The continents are located on tectonic plates and move around with them.

- The major tectonic plates include the Pacific, North America, South America, Africa, Eurasian, and Antarctic plates.
Plate Boundaries

• Much of the geological activity at the surface of the Earth takes place at the boundaries between tectonic plates.

• Tectonic plates may separate, collide, or slip past one another.

• Enormous forces are generated with these actions causing mountains to form, earthquakes to shake the crust, and volcanoes to erupt along the plate boundaries.
Plate Tectonics and Mountain Building

• Tectonic plates are continually moving around the Earth’s surface.

• When tectonic plates collide, slip by one another, or pull apart, enormous forces cause rock to **break and buckle**.

• Where plates collide, the crust becomes thicker and eventually forms mountain ranges, such as the Himalaya Mountains.
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Plate Tectonics
Earthquakes

- A **fault** is a break in the Earth’s crust along which blocks of the crust slide relative to one another.

- When rocks that are under stress suddenly break along a fault, a series of ground vibrations, known as **earthquakes**, is set off.

- Earthquakes are occurring all the time. Many are so small that we cannot feel them, but some are enormous movements of the Earth’s crust that cause widespread damage.
Earthquakes

• The measure of the energy released by an earthquake is called **magnitude**.

• The smallest magnitude that can be felt is 2.0, and the largest magnitude ever recorded is 9.5. Magnitudes greater than 7.0 cause widespread damage.

• Each increase of magnitude by one whole number indicates the release of **31.7** times more energy than the whole number below it.
Where do Earthquakes Occur?

- The majority of earthquakes take place at or near tectonic plate boundaries because of the enormous stresses that are generated when tectonic plates separate, collide, or slip past each other.
- Over the past 15 million to 20 million years, large numbers of earthquakes have occurred along the San Andreas Fault in California, where parts of the North America plate and the Pacific plate are slipping past one another.
Where do Earthquakes Occur?
Earthquake Hazard

- Scientists cannot predict when earthquakes will take place. However, they can help provide information about where earthquakes are likely to occur helping people prepare.
- An area’s earthquake-hazard level is determined by past and present seismic activity.
- Earthquake-resistant buildings, built in high-risk areas, are slightly flexible so that they can sway with the ground motion preventing them from collapsing.
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EarthQuakes
Volcanoes

- A volcano is a mountain built from magma, or melted rock, which rises from the Earth’s interior to the surface, and can occur on land or in the sea.

- Volcanoes are often located near tectonic plate boundaries where plates are either colliding or separating from one another.

- The majority of the world’s active volcanoes on land are located along tectonic plate boundaries that surround the Pacific Ocean.
Volcanoes: The Ring of Fire
Local Effect of Volcanic Eruptions

- Clouds of host ash, dust, and gases can flow down the slope of a volcano at speeds of up to **200 km/hr** and sear everything in their path.
- During an eruption, volcanic ash can mix with water and produce mudflow that runs downhill.
- In addition, ash that falls to the ground can cause buildings to collapse under its weight, bury crops, damage the engines of vehicles, and cause breathing difficulties.
Global Effects of Volcanic Eruptions

- Major volcanic eruptions can change Earth’s climate for several years.
- In large eruptions, clouds of volcanic ash and sulfur rich gases may reach the upper atmosphere, and spread across the planet reducing the amount of sunlight that reaches the Earth’s surface.
- The reduction in sunlight can cause a drop in the average global surface temperature.
Erosion

• The Earth’s surface is continually battered by wind and scoured by running water, which moves rocks around and changes their appearance.

• **Erosion** is the process in which the materials of the Earth’s surface are loosened, dissolved, or worn away and transported from one place to another by a natural agent, such as wind, water, ice or gravity.

• Erosion wears down rocks and makes them smoother as times pass. Older mountains are therefore smoother than younger ones.
Water Erosion

- Erosion by both rivers and oceans can produce dramatic changes on Earth’s surface.
- Waves from ocean storms can erode coastlines to give rise to a variety of landforms,
- Over time, rivers can carve deep gorges into the landscape.
Wind Erosion

• **Wind** also changes the landscape of the planet.
• In places where few plants grow, such as beaches and deserts, wind can blow soil away very quickly.
• Soft rocks, such as sandstone, erode more easily than hard rocks, such as granite do.
Tectonic Plates
1. Draw a chart like the one shown. Your chart can have as many columns and rows as you want.

2. In the top row, write the topics that you want to compare.

3. In the left column, write characteristics of the topics in the appropriate boxes.
Chapter 3
The Dynamic Earth
Section 2: The Atmosphere

DAY 1
The Atmosphere

• The **atmosphere** is a mixture of gases that surrounds a planet, such as Earth.

• **Nitrogen, oxygen, carbon dioxide, and other gases** are all parts of this mixture.

• Gases can be added to and removed from the atmosphere through living organisms.

• For example, animals remove oxygen when they breathe in and add carbon dioxide when they breathe out.
The Atmosphere

- **Volcanic eruptions** also add gases to the atmosphere, while vehicles both add and remove gases.
- The atmosphere also **insulates** Earth’s surface.
- This insulation **slows** the rate at which the Earth’s surface loses heat and keeps Earth temperature at which living things can survive.
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Volcanoes Erupting
Composition of the Atmosphere

• Nitrogen makes up 78 percent of the Earth’s atmosphere, and enters the atmosphere when volcanoes erupt and when dead plants and animals decay.

• Oxygen is the second most abundant gas in the atmosphere and is primarily produced by plants.

• In addition to gases, the atmosphere contains many types of tiny, solid particles, or atmospheric dust.
Composition of the Atmosphere

• In addition to nitrogen and oxygen, other gases such as argon, carbon dioxide, methane, and water vapor make up the rest of the atmosphere.
Air Pressure

- Earth’s atmosphere is pulled toward Earth’s surface by \textit{gravity} and as a result, the atmosphere is \textit{denser} near the Earth’s surface.
- Almost the entire mass of Earth’s atmospheric gases is located within \textbf{30 km} of the surface.
- Air also becomes less dense with \textit{elevation}, so breathing at higher elevations is more difficult.
Layers of the Atmosphere

- The atmosphere is divided into four layers based on temperature changes that occur at different distances above the Earth’s surface.
  - The Troposphere
  - The Stratosphere
  - The Mesosphere
  - The Thermosphere
Layers of the Atmosphere

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
- Ozone layer

Pressure (Pa)

Temperature (°C)

Altitude (km)
The Dynamic Earth

The Troposphere

• The **troposphere** is the lowest layer of the atmosphere in which temperature drops at a constant rate as altitude increases.

• This is the part of the atmosphere where weather conditions exist.

• The troposphere is Earth’s **densest** atmospheric layer and extends to 18 km above Earth’s surface.
The Stratosphere

- The **stratosphere** is the layer of the atmosphere that lies immediately above the troposphere and extends from about 10 to 50 km above the Earth’s surface.

- Temperature **rises as altitude increases** because ozone in the stratosphere absorbs the sun’s ultraviolet (UV) energy and warms the air.
The Stratosphere

- **Ozone** is a gas molecule that is made up of three oxygen atoms.
- Almost all of the ozone in the atmosphere is concentrated in the **stratosphere**.
- Because ozone absorbs **UV radiation**, it reduces the amount of UV radiation that reaches the Earth.
- UV radiation that does reach Earth can **damage living cells**.
The Mesosphere

• The layer above the stratosphere is the **mesosphere**.

• This layer extends to an altitude of about 80 km.

• This is the **coldest layer** of the atmosphere where temperatures have been measured as low as \(-93^\circ\text{C}\).
The Thermosphere

• The atmospheric layer located farthest from Earth’s surface is the thermosphere.

• Here, nitrogen and oxygen absorb solar radiation resulting in temperatures measuring above 2,000 °C.

• The air in the thermosphere is so thin that air particles rarely collide, so little heat is transferred, and would therefore not feel hot to us.
The Thermosphere

• The absorption of x-rays and gamma rays by nitrogen and oxygen causes atoms to become electrically charged.

• Electrically charged atoms are called ions, and the lower thermosphere is called the ionosphere.

• Ions can radiate energy as light, and these lights often glow in spectacular colors in the night skies near the Earth’s North and South Poles.
Energy Transfer in the Atmosphere

- **Radiation** is the energy that is transferred as electromagnetic waves, such as visible light and infrared waves.
- **Conduction** is the transfer of energy as heat through a material.
- **Convection** is the movement of matter due to differences in density that are caused by temperature variations and can result in the transfer of energy as heat.
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Section 1

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Atmosphere Song
Energy Transfer in the Atmosphere

1. Radiation moves energy through space in waves, to heat the Earth’s surface.

2. Near the Earth’s surface, air is heated by conduction.

3. Convection currents are caused by the unequal heating of the atmosphere.

20% absorbed by ozone, clouds, and atmospheric gases
5% reflected by the Earth’s surface
50% absorbed by the Earth’s surface
25% scattered and reflected by clouds and air
Heating of the Atmosphere

• Solar energy reaches the Earth as **electromagnetic radiation**, which includes visible light, infrared radiation, and ultraviolet light.

• About **half** of the solar energy that enters the atmosphere passes through it and reaches the Earth’s surface, while the rest of the energy is absorbed or reflected in the atmosphere by clouds, gases, and dust or it is reflected by Earth’s surface.
Heating of the Atmosphere

- The Earth does not continue to get warmer because the oceans and the land radiate the absorbed energy back into the atmosphere.
- Dark-colored objects absorb more solar radiation than light-colored objects, so dark colored objects have more energy to release as heat.
- This is one reason the temperature in cities is higher than the temperature in the surrounding countryside.
The Movement of Energy in the Atmosphere

- As a current of air, warmed by the Earth’s surface, rises into the atmosphere, it begins to cool, and eventually become denser than the air around it and sinks.

- This current then moves back toward the Earth until heated and less dense and then begins to rise again.

- The continual process of warm air rising and cool air sinking and moving air in a circular motion is called a convection current.
The Greenhouse Effect

• The **greenhouse effect** is the warming of the surface and lower atmosphere of Earth that occurs when carbon dioxide, water vapor, and other gases in the air absorb and reradiate infrared radiation.

• Without the greenhouse effect, the Earth would be too cold for life to exist.
The Greenhouse Effect

1. Sunlight passes through the glass into the car.
2. The interior absorbs radiant energy, changing it into heat.
3. The glass in the car stops most of the heat from escaping, increasing the temperature inside the car.
The Dynamic Earth

Section 1

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The Greenhouse Effect
The Greenhouse Effect

• The gases in the atmosphere that trap and radiate heat are called **greenhouse gases**.

• The most abundant greenhouse gases are **water vapor**, **carbon dioxide**, **methane**, and **nitrous oxide**, although none exists in high concentrations.

• The quantities of carbon dioxide and methane in the atmosphere vary considerably because of natural and industrial processes.
Chapter 3
The Dynamic Earth
Section 3: The Hydrosphere and Biosphere

DAY 1
The Hydrosphere

- The **hydrosphere** includes all of the water on or near the Earth’s surface.
- This includes water in the oceans, lakes, rivers, wetlands, polar ice caps, soil, rock layers beneath Earth’s surface, and clouds.
The Water Cycle

• The *water cycle* is the continuous movement of water from the ocean to the atmosphere to the land and back to the ocean.

• **Evaporation** is the change of a substance from a liquid to a gas.

• Water continually evaporates from the Earth’s oceans, lakes, streams, and soil, but the majority evaporates from the oceans.
The Water Cycle

• **Condensation** is the change of state from a gas to a liquid.

• Water vapor forms water droplets on dust particles, which then form clouds in which the droplets collide to create larger, heavier drops that then fall from the clouds as rain.

• **Precipitation** is any form of water that falls to the Earth’s surface from the clouds, and includes rain, snow, sleet, and hail.
The Dynamic Earth

Section 1

The Water Cycle

1. Evaporation
2. Condensation
3. Precipitation
Earth’s Oceans

- All of the oceans are joined in a single large interconnected body of water called the world ocean. The world oceans play important roles in the regulation of the planet’s environment.
Earth’s Oceans

• The largest ocean on Earth is the **Pacific Ocean** with a surface area of about 165,640,000 km².

• The deepest point on the ocean floor, the **Challenger Deep**, is found in the Pacific Ocean.

• The Challenger Deep is located east of the Philippine islands at the bottom of the Mariana Trench and is 11,033m below sea level which is deeper than Mount Everest is tall.
Earth’s Oceans

• Oceanographers often divide the Pacific Ocean into the **North Pacific and South Pacific** based on the direction of the surface current flow in each half of the Pacific Ocean.

• Surface currents in the Pacific move in a **clockwise** direction north of the equator.

• Surface currents in the Pacific move in a **counter-clockwise** direction south of the equator.
Earth’s Oceans

• The second largest ocean on Earth is the **Atlantic Ocean**, and covers about half the area of the Pacific Ocean, which is a surface area of about 81,630,000 km$^2$.

• Like the Pacific Ocean, the Atlantic Ocean can be divided into a north and south half based on the directions of surface current flow north and south of the equator.
Earth’s Oceans

- The **Indian Ocean** is the third largest ocean on Earth with a surface area of 73,420,000 km².

- The smallest ocean is the **Arctic Ocean**, which covers 14,350,000 km².

- The Arctic Ocean is unique because much of its surface is covered by floating ice, called **pack ice**, which forms when either waves or wind drive together frozen seawater, known as sea ice, into a large mass.
The Dynamic Earth

Section 1

Hydrosphere Video

Hydrosphere
The difference between ocean water and fresh water is that ocean water contains more salts.

**Salinity** is a measure of the amount of dissolved salts in a given amount of liquid.

Salinity is lower in places that get a lot of rain or in places where fresh water flows into the sea.

In contrast, salinity is higher where water evaporates rapidly and leaves the salts behind.
Ocean Water

• Most of the salt in the ocean is sodium chloride, which is made up of the elements sodium and chloride, although many other elements can be found in the ocean as well.
Bill Nye and Ocean Currents

Bill Nye and Ocean Currents
Temperature Zones

• The surface of the ocean is **warmed by the sun**, while the depths of the ocean, where sunlight never reaches, are very cold, just above freezing.

• Surface waters are stirred up by **waves and currents** so the warm surface zone may be as much as 350 m deep.

• Below the surface zone is the **thermocline**, which is a layer about 300 to 700 m deep where the temperature falls rapidly.
**Temperature Zones**

**Surface Zone** The surface zone is the warm, top layer of ocean water. Sunlight heats the top 100 m of the surface zone. Surface currents mix the heated water with cooler water below.

**Thermocline** Water temperature in this zone drops faster with increased depth than it does in the other two zones.

**Deep Zone** This bottom layer extends from the base of the thermocline to the bottom of the ocean. The temperature in this zone averages 2°C.
A Global Temperature Regulator

- One of the most important functions of the world ocean is to **absorb and store energy** from sunlight which in turn regulates temperatures in Earth’s atmosphere.

- Because the ocean both absorbs and releases heat slower than land, the temperature of the atmosphere changes more slowly.

- If the ocean did not regulate atmospheric and surface temperatures, temperatures would be too extreme for life to exist on Earth.
A Global Temperature Regulator

- Local temperatures in different areas of the planet are also regulated by the world ocean.
- Currents circulate warm water causing land areas they flow past to have climates that are more moderate.
- For example, the British Isles are warmed by the waters of the Gulf Stream.
Ocean Currents

- Stream like movements of water that occur at or near the surface of the ocean are called **surface currents**.
- Surface currents are **wind driven** and result from global wind patterns.
- Surface currents can be **warm or cold** water currents. However, currents of warm water and currents of cold water do not readily mix with one another.
Ocean Currents
Ocean Currents

- **Deep currents** are streamlike movements of water that flow very slowly along the ocean floor.

- Deep currents form when the cold, dense water from the poles **sinks** below warmer, less dense ocean water and flows toward the equator.

- The densest and coldest ocean water is located off the coast of Antarctica and flows very slowly northward producing a deep current called the Antarctic Bottom Water.
Fresh Water and River Systems

- **Fresh water** is water that contains insignificant amounts of salts.
- Most of the fresh water is locked up in icecaps and glaciers while the rest is found in places like lakes, rivers, wetlands, the soil and atmosphere.
- A **river system** is a network of streams that drains an area of land and contains all of the land drained by a river including the main river and all its smaller streams or rivers that flow into larger ones, or tributaries.
Ground water

• Rain and melting snow sink into the ground and run off the land. Most of this water trickles down through the ground and collects as **groundwater**.

• Although it makes up only 1 percent of all the water on Earth, groundwater fulfills the human need for fresh drinking water, and supplies agricultural and industrial need.
Aquifers

- A rock layer that stores and allows the flow of groundwater is called an **aquifer**.
The Biosphere

- The **biosphere** is the part of Earth where life exists, extending about 11 km into the ocean and about 9 km into the atmosphere.
- The materials that organisms require must be continually recycled.
- **Gravity** allows a planet to maintain an atmosphere and to cycle materials.
- Suitable combinations that organisms need to survive are found only in the biosphere.
The Biosphere

- The **biosphere** is located near Earth’s surface because most of the sunlight is available near the surface.
- Plants need sunlight to produce their food, and almost every other organism gets its food from plants and algae.
- Most of the algae float at the surface of the ocean and is known as phytoplankton.
Energy Flow in the Biosphere

• The energy used by organisms must be obtained in the biosphere and must be constantly supplied for life to continue.

• When an organism dies, its body is broken down and the nutrients in it become available for use by other organisms.

• This flow of energy allows life on Earth to continue to exist.
Energy Flow in the Biosphere

- **Closed systems** are systems that cannot exchange matter or energy with its surroundings.

- **Open systems** are systems that can exchange both matter and energy with its surroundings.

- Today, the Earth is essentially a closed system with respect to matter, but an open system for energy as energy travels from plant to animal, which is eaten by other animals.

- In the process, some energy is lost as heat to the environment.