Chapter Three: The Dynamic Earth

I. **Earth as a System: Some scientists divide the Earth into 4 main parts – geosphere, atmosphere, hydrosphere, and biosphere. We will be taking an overview of these parts in this chapter.**

A. **Discovering Earth's Interior**

1. **Geosphere: solid part of the Earth that consists of all rock and the soils and sediments on the Earth's surface; extends from the center of the Earth to its crust**
2. **Most of the geosphere is located in the Earth's interior, yet the deepest well that has been drilled is only about 12 km deep.**
3. **Scientists gather information about the Earth's interior by studying seismic waves.**
4. **Seismic waves are altered by the nature of the material through which they travel.**
   a. **By looking at the changes in speed and direction of seismic waves, scientists have learned that there are different layers making up the interior of the Earth and have inferred what the composition is of each of these layers.**
      i. **Crust: Earth's thin outer layer, made almost entirely of light elements**
      ii. **Mantle: underneath the crust; makes up most of Earth's mass; made of rocks of medium density**
      iii. **Core: center of the Earth, composed of the densest elements**

5. **By examining the physical properties of the geosphere, scientists have divided the Earth into 5 layers. Working from the surface of the Earth inward, they are:**
    a. **Lithosphere – outer layer; cool and rigid; 15 – 300 km thick; includes the crust and uppermost part of the mantle; made up of tectonic plates**
    b. **Asthenosphere – plastic, solid layer of the mantle that is made of rock that flows very slowly, allowing the tectonic plates to move on top of it; 250 km thick**
    c. **Mesosphere – lower layer of the mantle; "middle sphere;" 2,550 km thick**
    d. **Outer Core – dense, liquid layer of nickel and iron; 2,200 km thick**
    e. **Inner Core – a dense, solid sphere of mostly nickel and iron at the center of the Earth; temperature estimated between 4,000 °C to 5,000 °C; remains solid despite high temperature because of enormous pressure**
6. **Plate Tectonics**
    a. **Plates glide across the asthenosphere like ice in a pond.**
    b. **Major plates: Pacific, North American, South American, African, Eurasian, Antarctic**
    c. **At the plate boundaries, much geologic activity takes place.**

i. **Plates can separate, collide, slip past one another; the huge forces and energy involved can lead to earthquakes or cause volcanoes to erupt.**
ii. **Where plates collide, the crust becomes thicker and eventually mountain ranges are formed.**

7. **Earthquakes**
   a. **Fault: break in the Earth's crust along which blocks of the crust slide relative to one another**
   b. **When rocks under stress suddenly break along a fault, ground vibrations are set off – an earthquake.**
   c. **Richter scale: quantifies the amount of energy released by an earthquake; known as its magnitude**
      i. **Smallest felt is about 2.0, largest recorded is 9.5**
      ii. **Each whole number is an increase of 31.7 times more energy than the level below it.**
   d. **Majority of earthquakes take place at or near tectonic plate boundaries due to stresses caused by plates moving against one another.**
   e. **One of the most famous: San Andreas fault which runs the length of California**

f. **Not all earthquakes happen along plate boundaries though – Charleston, SC and Reading, PA have had earthquakes!**

8. **Volcanoes**
   a. **Volcanoes are mountains**
   b. **built from magma that rises from the Earth's interior to the surface.**
   c. **Often located near tectonic plates, specifically where plates are either colliding or separating from each other.**
   d. **They can occur both on land or under the sea (may break the surface of the sea as islands).**
   e. **Ring Of Fire: contains nearly 75% of the world's active land volcanoes; located along the tectonic plate boundaries surrounding the Pacific Ocean**
   f. **Local effects of volcanoes – immediate and total destruction of everything nearby; mudflows and ash are just as destructive**
   g. **Global effects: major eruptions can cause a change in climate for several years**
      i. **Clouds of ash and gas reach upper atmosphere and reduce the amount of sunlight reaching the planet consequently dropping the global temperature by several tenths of a degree Celsius over a period of several years**

ii. Mount St. Helens, Mount Pinatubo, Krakatoa

9. Erosion
   a. Earth's surface is constantly battered by the weather – wind, water, etc.
   b. erosion – generally, the removal and transport of surface material
   c. The forces of wind and water (influenced by local specifics of vegetation, soil composition, etc.) do much to shape and carve the landscape of the Earth over long periods of time.

II. The Atmosphere – One of the ways that the Earth is unique is its atmosphere. The role it plays is crucial to the Earth's ability to support life – without this insulating blanket, Earth's temperature would fluctuate too greatly to support life as we know it. The existence of lots of liquid water in combination with our atmosphere allows Earth to stay at relatively stable temperatures. In addition, the protective ozone layer also allows life to exist by keeping out deadly UV rays from the sun.

A. Composition of the Atmosphere
   1. 78% nitrogen, 21% oxygen, and 1% "other" including argon, carbon dioxide, methane, and water vapor
   2. Solids – atmospheric dust – mostly soil but also includes salt, ash (fires and volcanic), skin, hair, pollen, bacteria, viruses, etc.

3. **air pressure: gravity pulls the atmosphere toward the Earth's surface, and so the atmosphere is more dense near the surface of the Earth – almost the entire mass of the atmosphere is located within 30 km of the Earth's surface.**

B. Layers of the Atmosphere – starting from closest to Earth's surface in order: Troposphere, Stratosphere, Mesosphere, Thermosphere

1. **Troposphere: about 18 km thick, this is where almost all weather occurs; densest layer; temperature decreases as altitude increases**
2. **Stratosphere: from 18 km – 50 km up; contains the ozone layer; many jets fly in lower portion of this layer; temperature rises as altitude increases due to ozone absorbing the sun's UV energy and warming the air**
3. **Mesosphere: from 50 km to 80 km up; coldest layer of the atmosphere**
4. **Thermosphere: 80 km and up; nitrogen and oxygen absorb solar radiation causing the thermosphere to be the hottest layer by far but there are so few air particles that heat transfer rarely occurs**
   a. **Ionosphere – lower portion of the thermosphere, atoms here become electrically charged from absorbing solar radiation and sometimes radiate light energy - e.g. aurora borealis (Northern Lights)**

C. **Energy in the Atmosphere: There are 3 ways to transfer energy from the sun – radiation, conduction, and convection**
    1. **radiation: the transfer of energy by electromagnetic waves such as visible light and infrared waves; across space and the atmosphere**
    2. **conduction: flow of heat through matter from a warmer object to a colder object in direct contact with each other**
    3. **convection: transfer of heat by fluid currents that are moving as a result of differences in density caused by temperature variations**

D. **Heating of the Atmosphere**
    1. **Our planet only receives about two-billionths of the energy released by the sun.**
    2. **About half of the solar energy that enters the atmosphere passes through and reaches the Earth's surface. The rest is absorbed or reflected by clouds, gases, dust, or reflected by the Earth's surface.**
    3. **Oceans and land radiate the energy they have absorbed back into the atmosphere.**

E. **Movement of Energy in the Atmosphere**
    1. **Air moving upward, downward, or sideways causes Earth's weather.**
    2. **Currents of less dense air that has been warmed by Earth's surface travel upward into the atmosphere while currents of denser colder air travel down to the ground.**

3. **The rising warm air begins to cool and the sinking cold air begins to warm, causing them to change directions.**
4. **This circular pattern is called convection current. See figure 15 on pages 70-71.**

F. The Greenhouse Effect

1. **The gases in the atmosphere act like the glass in a greenhouse, trapping heat.**
2. **Sunlight heats the surface of the Earth, which radiates heat back to the atmosphere.**
3. **Some of this radiated heat escapes into space.**
4. **The remainder of the heat is absorbed by certain gases in the atmosphere (greenhouse gases like carbon dioxide and methane), which warms the air.**
5. **This heat is now radiated back to the surface of the Earth, raising the temperature.**
6. **Without the greenhouse effect, Earth would be too cold for life to exist as we know it.**
7. **However, the excess of greenhouse gases (namely carbon dioxide) has caused the temperature of the Earth to increase alarmingly over the last 50-100 years.**
8. **The excess carbon dioxide is generally from human activity requiring the burning of fossil fuels.**
9. **This increase in the temperature of the Earth from the greenhouse effect is known as global warming.**

G. Changes in the Atmosphere

Before life: mostly water vapor, CO_2 and sulfur gases from erupting volcanoes

First life: obtained energy from the chemicals in the ancient seas

1. **Eventually, bacteria evolved that could combine H_2O, CO_2 and sunlight to get food (photosynthesis).**
2. **resulted in lots of oxygen gas being put into the atmosphere, making it possible for other forms of life to evolve**

H. Element Cycles

1. **Cycles of oxygen, carbon dioxide, water vapor, and nitrogen moving from the atmosphere, through bodies of organisms, and back to the atmosphere have been going on for billions of years.**
2. **part of the carbon of the Earth is cycled, but most is stored in the bodies of organisms (alive and dead)**

I. Human impacts on the atmosphere:

1. **increased greenhouse effect (global warming)**
2. **pollution**
3. **ozone depletion**

III. The Hydrosphere

A. The hydrosphere includes all of the water on or near the Earth's surface such as oceans, lakes, polar ice caps, groundwater, and clouds.

1. **70% of the Earth's surface is covered by water**
   a. **98% of the hydrosphere is salt water located mostly in the oceans (World Ocean)**
   b. **2% of the hydrosphere is fresh water; 2/3 of the fresh water is frozen in ice caps or glaciers**
2. **Most life forms on Earth are supported by fresh water, but there is very little available**
3. **2 types of fresh water: surface & ground**
   a. **surface water includes lakes, streams, rain runoff**
   b. **ground water – flows beneath the surface of the Earth through small spaces in and between rocks**
      i. **aquifer: a rock layer that stores and allows the flow of groundwater; hold water much the same way that a sponge does**
      ii. **artesian wells: water which flows to the surface due to high pressure underground, usually follows a crack in the rocks – springs**
4. **Temperature Regulation**
   a. **The world ocean has a huge role in regulating the temperature of the Earth.**
   b. **The ability for water, (especially a body of water as big as the world ocean), to**

absorb and store energy from sunlight has a huge impact in keeping the temperature of the Earth relatively steady.

c. Over half the solar radiation that reaches the Earth's surface is absorbed by the world ocean, and energy is absorbed and released more slowly by water than by land.

d. Without the world ocean, the temperatures on Earth would be too extreme for life to exist.

B. Changes in the Hydrosphere: The shape and location of the Earth's oceans have changed over time; some changes are slow, some happen in cycles

1. ice ages: long periods of cooling during which glaciers move from the poles to cover much of the Earth's surface

After an ice age, glaciers retreat back to the poles.

a. have been at least 5 major ice ages in the Earth's history
b. most recent ice age ended 10 – 12,000 years ago

2. Movement of Glaciers:

a. large scale weathering and erosion
b. relocation of huge rocks and other materials
c. most recent ice age effects:
   i. Great Lakes
   ii. Cape Cod peninsula

3. **Cause of ice ages is unknown, but many hypotheses exist – wobbling of Earth on its axis**

4. **El Nino – occurs when the annual December current of warm, nutrient poor water lasts several months instead of the normal few weeks; this current flows along the coast of South America**
   - **a. Effects of El Nino**
     - **i. change in water temperature and nutrients causes fish populations to decrease**
     - **ii. fishing industry**
     - **iii. poultry and egg industries (use fish meal)**
   - **b. usually upsets typical weather patterns, which often leads to destroyed crops particularly bad years: 1982, 1998**

No one is sure of the cause of El Nino, but it usually runs in cycles, happening every 4 to 7 years.

IV. The Biosphere

A. Composed of the parts of the Earth that support life, it's a narrow layer around the Earth. A commonly used comparison: if the Earth is an apple, then the biosphere is the skin of the apple.

1. **only about 20 km thick, (about 11 km into the ocean and 9 km into the atmosphere)**

2. ***most*** **organisms live in a narrower range, about 500m below the surface of the ocean to about 6 km above sea level**
3. **Reasons for narrower range:**
    a. **pressure is too high deep below ocean surface**
    b. **oxygen is too thin and temperatures are too low in higher altitudes**