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Climate Change: The Greenhouse Effect: Chapter 8.6

The Greenhouse Effect

- Even without the climate system, Earth would reach a balance of energy
- The amount of energy absorbed would equal to the amount of energy emitted. However, without a climate system, Earth would be much colder than it is
- The climate system moderates Earth’s temperature by trapping and storing energy from the Sun and distributing it around the world. As a result, the air temperature remains relatively constant each day and night and across large regions of earth

What is the Greenhouse Effect?

- The atmosphere allows much of the higher-energy radiation from the Sun to pass through it.
- This radiation is absorbed by Earth’s surface, becoming **thermal energy**. As a result, Earth warms up.
- Earth’s warm surface then emits lower-energy infrared (IR) radiation. Different gases of the Earth’s atmosphere trap much of the IR radiation.
- Then, these gases radiate the energy equally in all directions, which means that 50% of the radiation gets sent back towards Earth’s surface (Thus, the Earth gets warmed even more)
- If Earth did not have a climate system, the average global temperature would be about -18°C, but because of the climate system’s greenhouse effect, the average temperature is around 15°C
- The greenhouse effect is a natural process that has been happening for millions of years. It is the process that traps the energy

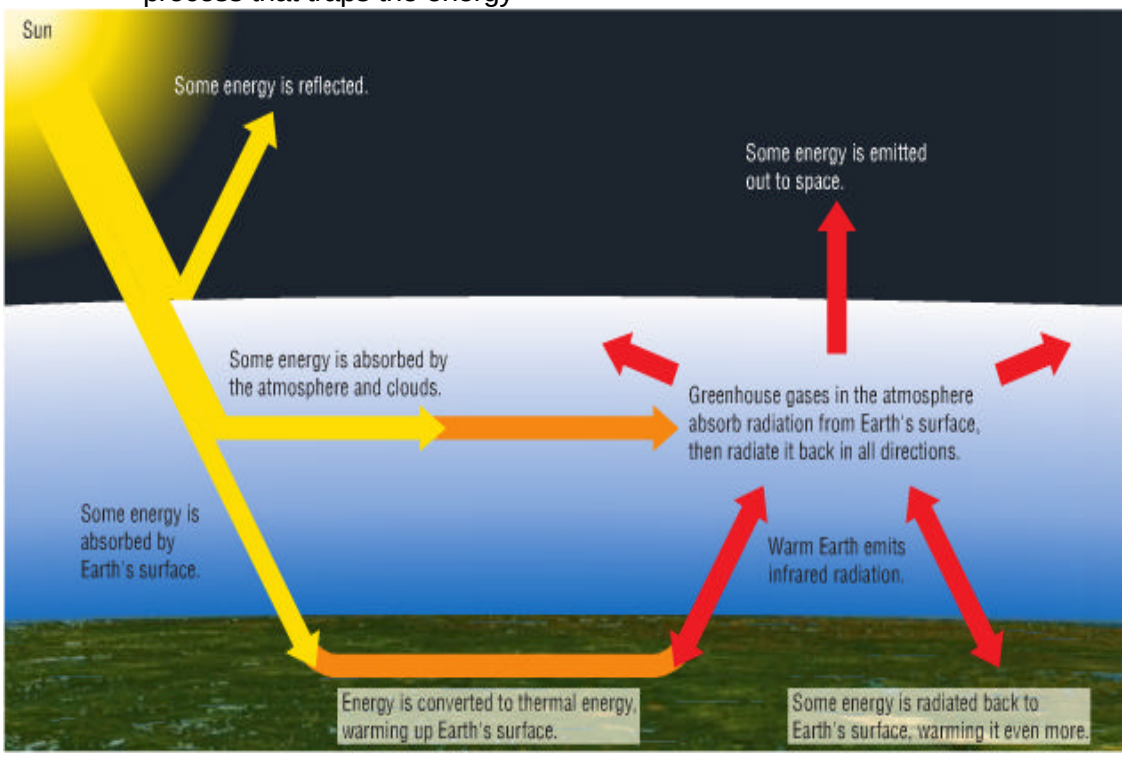

Figure 1 High-Energy radiation from the Sun enters the atmosphere. Gases and clouds ir the atmosphere trap some of the infrared radiation from the Earth’s surface and radiate it back. This is the greenhouse effect

Greenhouse Gases

- Most of the air in the atmosphere is made up of nitrogen and oxygen gases. These gases do not absorb radiation from Earth’s surface. The greenhouse effect is caused by gases that exist in very low concentrations in the atmosphere (**greenhouse gases**)
- The most important greenhouse gases are water vapour, H_2O, and carbon dioxide, CO_2. Other less significant gases are methane, CH_4, repospheric ozone, O_3, and nitrous oxide, N_2O
- Their contribution to the greenhouse effect is determined by their concentration in the atmosphere and by how much thermal energy each molecule of gas can absorb

Carbon Dioxide

- Earth’s atmosphere contains only 385 ppm (parts per million) carbon dioxide, or 0.0385%
- Carbon dioxide is estimated to cause up to a quarter of the natural greenhouse effect on Earth
- Natural sources of atmospheric carbon dioxide include volcanic eruptions, the burning of organic matter, and cellular respiration of plants and animals
- The carbon cycle is the movement of carbon through living things, the lithosphere, the atmosphere, and the hydrosphere. Living things and oceans are important **carbon sinks** (a reservoir such as an ocean or forest, that absorbs carbon dioxide from the atmosphere and stores the carbon in another form)
- Tress and other plants capture carbon dioxide during photosynthesis and use it to grow. When trees decompose or burn, the carbon is released into the atmosphere as carbon dioxide. In the ocean, carbon dioxide dissolves and some forms solid calcium carbonate, which sinks to the bottom of the ocean

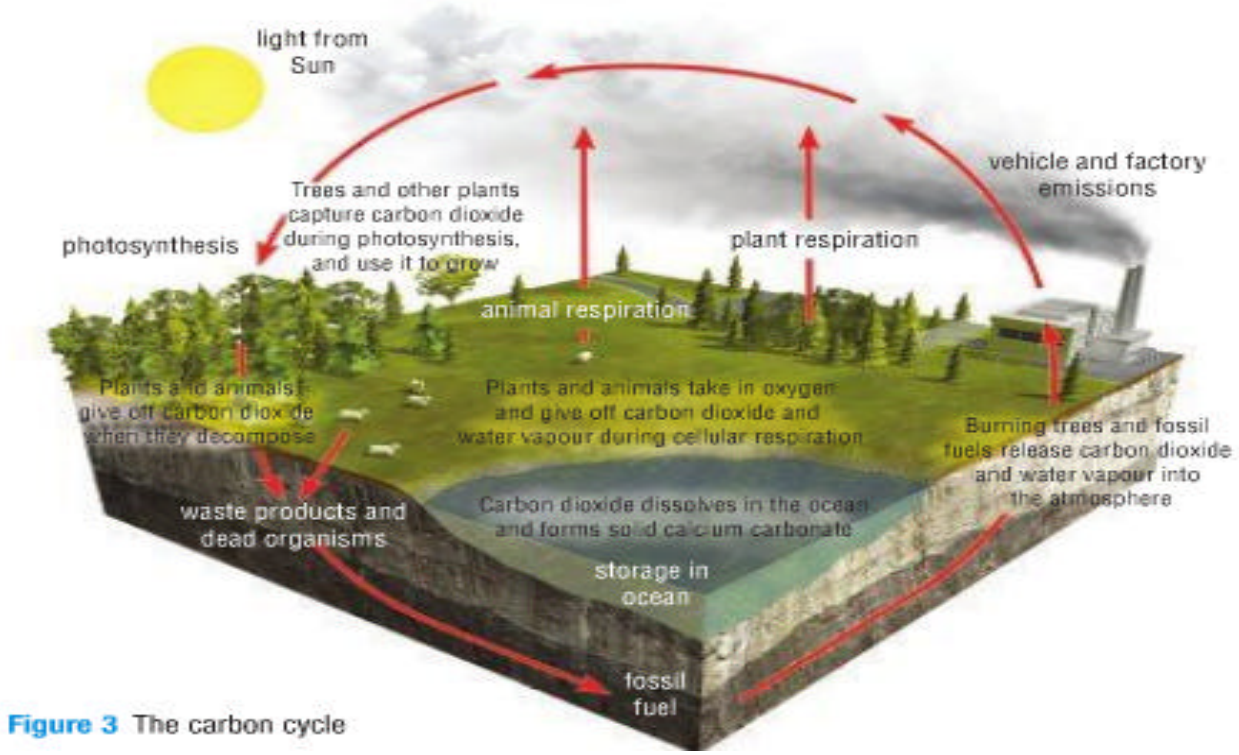

Figure 3 The carbon cycle

Water Vapour

- About 66.7% of Earth’s natural greenhouse effect is caused by water vapour in the atmosphere. The quantity of atmospheric water vapour depends on the temperature of the atmosphere. It varies from trace amounts to about 4%
- Water evaporates readily when it is heated. Warmer air can hold more water vapour. Thus, as Earth’s temperature increases, more liquid water becomes water vapour. Because water vapour traps energy, the more water vapour there is in the atmosphere, the warmer Earth becomes
- This type of relationship is called a feedback loop – the cause (here, high temperature) creates an effect (more water vapour in the air) that affects the original cause (warming Earth further). In a positive feedback loop, the effect enhances the original cause. Water vapour and temperature are related in a positive feedback loop. In a negative feedback loop, the effect decreases the original cause
- Methane
- There is a lot less methane in the atmosphere than Carbon Dioxide
- A molecule of methane can absorb much more thermal energy than a molecule of carbon dioxide
- A methane molecule is about 23 times more powerful as a greenhouse gas than a molecule of carbon dioxide
- Methane comes from both natural and human sources. It is produced naturally by biological processes such as plant decomposition in swamps and animal digestion
- Before the industrial age, the concentration in the atmosphere was 0.700 ppm (or 700 ppb) and now it is 1.785 ppm (or 1785 ppb)

Figure 5 Bacteria that live in swan and other wetlands, and in animal digestive systems, produce methan as a by-product.

Ozone

- Ozone gases exist naturally in the stratosphere where it forms a layer protecting Earth’s surface from the Sun’s higher-energy Ultraviolet radiation
- Lower down in the troposphere, ozone acts as a greenhouse gas. Scientists do not have a clear picture of what the average concentration of tropospheric ozone is because it changes rapidly. They do know that it contributes to the greenhouse effect

Nitrous Oxide

- A molecule of Nitrous Oxide, N_2O, is almost 300 times more effective than a molecule of carbon dioxide as a greenhouse gas
- A very small concentration of nitrous oxide is present in the atmosphere
- Before the industrial age, the concentration of nitrous oxide was 270 ppb (0.27 ppm) now it is 321 ppb (0.321 ppm)
- Like carbon dioxide and methane, nitrous oxide is produced both naturally (by reactions of bacteria in soil and water) and from human sources

Figure 6 Tropical soils are a significa source of nitrous oxide.

- CO_2, CH_4, N_2O, and other greenhouse gases are present in the atmosphere in tiny quantities

How Do Greenhouse Gases Trap Infrared Radiation?

- Nitrogen gas and oxygen gases each consist of two identical atoms. The two atoms in these molecules can only vibrate in one way: back and forth. When infrared radiation reaches these molecules, they cannot absorb it well
- Water, carbon dioxide, and methane consist of three or more atoms, and have different types of atoms. Nitrous oxide also has three atoms. The atoms in these molecules can vibrate and wiggle in many ways, and can absorb different types of energy. Thus, when infrared radiation reaches water vapour, or methane, these molecules trap the infrared energy and re-radiate it back out in every direction

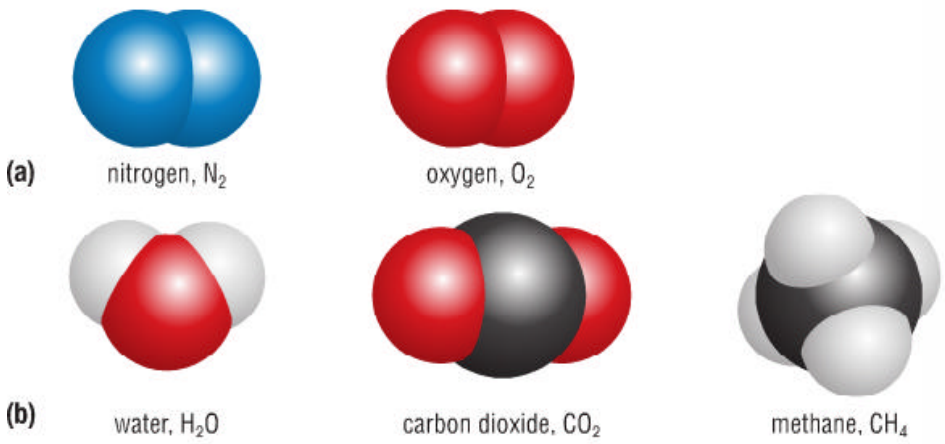

Figure 7 (a) Nitrogen and oxygen are very poor absorbers of infrared radiation because they consist of only two atoms. (b) Water, carbon dioxide, and methane molecules contain several atoms as well as different types of atoms. These molecules can absorb different types of energy, including infrared radiation.

Summary

- The climate system traps and stores energy through the greenhouse effect
- The greenhouse effect is caused by gases in the atmosphere absorbing the infrared radiation that is emitted from Earth’s surface and radiating it back again.
- The greenhouse effect warms the atmosphere and Earth’s surface so that life can exist on Earth
- Water vapour, carbon dioxide, methane, ozone, and nitrous oxide are important greenhouse gases because they trap Earth’s infrared radiation
- Living things, especially forests and oceans, are carbon sinks because they remove carbon dioxide from the atmosphere and store the carbon atoms in a different form

Review Questions

1. Explain why the greenhouse effect is important to life on Earth.

2. Describe how the greenhouse effect in the atmosphere works.

3. a) Write a definition of “greenhouse gas”

   b) Name the two most important greenhouse gases that occur naturally in the atmosphere.

4. If forests serve as important sinks for greenhouse gases, describe how the past ice ages might have affected the concentration levels of carbon dioxide in the atmosphere.

5. Briefly explain the carbon cycle.

6. Give one natural source for each of the following greenhouse gases:
   a. Carbon dioxide

   b. Methane

   c. Nitrous oxide

   d. Water Vapour

7. Explain how greenhouse gas molecules, in contrast to oxygen and nitrogen molecules, trap infrared radiation