CHAPTER 1

Global Change

Learning Objectives

After reading this chapter, students should be able to:

- Understand the major global environmental problems.
- Know about anthropogenic greenhouse gases.
- Know about fundamental components of the Earth system.
- Differentiate between global warming and the greenhouse effect.
- Know how the stratospheric ozone layer is affected by anthropogenic gases.
- Know the effect of deforestation on biodiversity.
- Understand the relationship between surface temperature and atmospheric CO_2 concentration.
- Know how reduced solar luminosity would have affected the early Earth.
- Know what the Gaia hypothesis is.
- Know how past surface temperatures are determined.

Review Questions

1.)

a. What is meant by "anthropogenic greenhouse gases"?

Humans cause changes to the environment that are called "anthropogenic." Humans have generated local pollution ever since they first developed agricultural societies. By the burning of fossil fuels (fuels such as coal, oil, and natural gas that are composed of the fossilized remains of organisms) and by deforestation, humans produce the most abundant anthropogenic greenhouse gas (CO_2) on Earth. Greenhouse gases such as freons (CFCs) are entirely anthropogenic, while CO_2, CH_4, and N_2O are partly anthropogenic.

b. Name three such gases that are currently increasing in concentration in Earth's atmosphere.

There are 4 greenhouse gases discussed in the textbook:
1- Carbon dioxide (CO_2)
2- Freons (CFCs)
3- Methane (CH_4)
4- Nitrous oxide, N_2O
Freons, though, are currently *decreasing* in concentration because they have been banned in order to protect the ozone layer.

2.)

a. What are the four fundamental components of the Earth system?

The Earth system is composed of four parts:

i. The atmosphere: A thin layer of gases that surrounds Earth
ii. The hydrosphere: Composed of various reservoirs of water, including ice
iii. The biota: Includes all living organism
iv. The solid Earth: Includes all rocks, including those in both the crust and the mantle. The iron core is also part of the Earth system because it is there that Earth's magnetic field is generated.

3.) Explain the difference between global warming and the greenhouse effect.

Greenhouse gases are gases that warm a planet's surface by absorbing outgoing infrared radiation (radiant heat) and reradiating some of it back toward the surface. This process is called the greenhouse effect. The greenhouse effect is a natural physical process that operates in all planetary atmospheres. Global warming is a warming of Earth's atmosphere caused by an anthropogenic enhancement of the greenhouse effect.

4.)

a. By how much has Earth's atmospheric CO_2 concentration increased since the year 1800?

389 ppm – 280 ppm = 109 ppm (answer written in 2009)

b. How do we know this?

Keeling's data show that the mean atmospheric CO_2 level for today is around 389 ppm. The ice core measurements show that the preindustrial CO_2 concentration (the value circa 1800) was about 280 ppm, so the CO_2 concentration has increased by 109 ppm.

The average rate of increase in the CO_2 concentration since 1800 has been 109 ppm/209 yr, or about 0.5 ppm /yr.

c. What are thought to be the primary causes of this increase?

Apparently, humans have been responsible for the entire 39% increase in atmospheric CO_2 concentration over the past two centuries. Deforestation of North America in the 19^{th} century contributed to the initial rise, and then fossil fuel burning and tropical deforestration contributed after that.

5.) Cite two ways in which chlorofluorocarbons can affect the environment.

The chlorofluorocarbons (CFCs) are synthetic compounds containing chlorine, fluorine, and carbon. These trace gases have warmed the climate slightly by adding to the greenhouse effect. The CFCs have also been implicated in the destruction of stratospheric ozone.

6.)

a. How far back in time do direct measurements of Earth's surface temperature extend?

Since 1861 scientists have made accurate atmospheric temperature measurements using thermometers.

b. Why is it difficult to determine accurately the long-term temperature trend?

Problems exist with historical temperature data. For instance:
Location of stations: Stations located in cities are subject to a "heat island effect" that causes local temperatures to increase with time.
Coverage in time and space: Some parts of the world have more coverage than the others. There is very little coverage, for example, in the southern oceans.

7.) How might the burning of coal have had opposing effects on climate during the 20^{th} century?

Burning of coal adds CO_2 to the atmosphere and hence warms the surface by increasing the greenhouse effect. However, one possible explanation for the 1940 to 1970 cooling trend is that it was caused by increased reflection of sunlight by sulfate aerosol particles. These tiny airborne particles are formed from sulfur dioxide (SO_2) emitted by the burning of coal.

8.) Why is stratospheric ozone important to humans?

Stratosphere ozone is important to living organisms because it absorbs many of the Sun's harmful ultraviolet rays. Ultraviolet radiation causes skin cancer and other health problems in humans.

9.) To what two global environmental problems does tropical deforestation contribute?

Tropical deforestation reduces the complexity of the landscape so biodiversity is reduced, and tropical deforestation also adds CO_2 to the atmosphere and, hence, adds to global warming.

10.) How are hydrogen isotopes used to infer polar temperature records?

Ice cores can be used to estimate past surface temperatures by looking at oxygen or hydrogen isotopes. By analyzing the isotopic composition of frozen water-ice

in polar ice cores, we can learn something about the local temperature at the time the ice formed. Warmer water temperatures speed up the evaporation rates of both H_2O and HDO. HDO represents water molecules that contain deuterium. Warmer temperatures correspond to a higher HDO content in the snow that falls over Antarctica and in the ice that forms from the snow.

11.) How is past surface temperature

a. Determined from the Vostok ice core?

The temperature changes, ΔT, were determined from measured values of the deuterium content of the Vostok ice core. The section of the Vostok ice core that has been fully analyzed is about 3.5 km deep and it extends back for almost 450,000 years. The Dome C record mentioned in the text is about 3.3 km deep and extends back about 800,000 years.

b. Related to atmospheric CO_2 content?

Vostok results showed that atmospheric CO_2 and CH_4 concentrations have varied in concert with surface temperature. As levels of the greenhouse gases CO_2 and CH_4 increased, the magnitude of the greenhouse effect also increased, and the climate became warmer. But the temperature curve actually leads the CO_2 curve slightly, indicating that cause and effect are mixed up in this record. This is a prime example of why we need to consider the entire coupled *system*,

12.) Why is iridium a good indicator of impacts by extraterrestrial bodies?

Iridium is a metal in the platinum group of elements, which are very scarce in rocks of Earth's crust, because they are mostly dissolved in its molten iron core. These elements are always raining down on Earth as small particles of debris from asteroids or comets. The rate at which such debris hits Earth is known fairly accurately from measurements of the iridium abundance in cores drilled into the ocean floor.

13.)

a. How has solar luminosity changed during the past 4.6 billion years?

When the Sun first formed 4.6 billion years ago, it is believed to have been about 30% less luminous than it is today. The Sun's luminosity increased slowly at first and then more rapidly as the buildup of helium in its core continued. At present, the Sun is thought to be brightening by about 1% every hundred million years.

b. What is the fundamental cause of this change?

The Sun produces its energy through nuclear fusion → Four hydrogen nuclei (^1H) fuse to form one helium nucleus (^4He)→ The core becomes denser → The core contracts under its own gravity → The core's temperature increases → The rate of nuclear fusion increases → Energy production within the Sun's core rises → The amount of energy emitted at the surface increases → The Sun's luminosity increases as it depletes its hydrogen fuel.

14.) What is the Gaia hypothesis, and what does it say about the importance of life on this planet?

The Gaia hypothesis states that Earth is a self-regulating system in which the biota plays an integral role. Also, this hypothesis suggests that the biota manipulate their environment for their own benefit or even, by optimizing the conditions for life, for the benefit of all living things.

Critical Thinking Problems

1.) Which of the three modern global change problems discussed in this chapter--global warming, ozone depletion, or loss of biodiversity--do you consider to be the most serious? Give reasons for your answer. If you wish, include information drawn from other sources.

There are different opinions for this problem; one can argue that any one of them is the most significant problem. We have listed reasons students could use for all three of these problems below.

Students can argue that global warming is the most serious problem because:

- It affects the greatest number of people
- Migration of marine animals could result
- Rising sea level could result
- Cold climate species might die
- Ozone depletion and deforestation are currently both confined to particular areas whereas global warming is truly global

Students can argue that ozone depletion is the most serious problem because:

- It causes the most immediate damage to our planet and its inhabitants
- It can cause skin cancer
- It occurs faster than global warming, because global temperatures only rise a few degrees in 100 years , whereas severe ozone depletion occurred within less than decade over Antarctica.
- It could conceivably become global if stratospheric chlorine reached levels higher than those of today

Students can argue that loss of biodiversity is the most serious problem because:

- There is potential for recovery for the other problems: the ozone layer could recover within a few generations and greenhouse gas concentrations should return to "normal" within a few million years
- The recovery rate for species following extinction is tens of millions of years
- Once a species is gone, it is gone for good
- It could cause an imbalance in the Earth's ecosystem and economy
- Deforestation also contributes to global warming

2.) How do global warming, ozone depletion, and loss of biodiversity compare with other environmental and social problems that the world faces today? You may wish to list the major problems, as you see them, in decreasing order of importance. Justify your answer with an explanation.

As in the first problem there are different views on this question.

Global warming, ozone depletion, and loss of biodiversity are more important than the other environmental and social problems because:

- They are too large in scale to consider secondary to any other problems. These three affect the entire planet and could alter the future of human life on Earth and Earth itself.
- We could all die or suffer because of global warming, ozone depletion, and loss of biodiversity, but disease and homelessness could all be prevented, in theory at least.

Global warming, ozone depletion, and loss of biodiversity are less important than the other environmental and social problems because:

- They are not as immediately pressing as other social problems
- The biggest problems are poverty and war
- The Earth as a system has ways of healing and evolving to support life and will continue to do so as long as it exists. (But don't count on this to solve problems like ozone depletion and global warming!) However, society has no system of checks and balances.

Resource Guide

Video/Film:

An Inconvenient Truth
Al Gore (2 hours, color)
This is by far the most up-to-date and powerful movie about the perils of global warming. Although Gore himself is politically controversial, the science in this movie is for the most part very good. A "must show" if you are teaching this course.

The Pleasure Planet: Can the Earth Be Saved?
Films for the Humanities and Sciences
www.films.com
Home to billions of human beings, Earth is reaching an ecological crisis point. By analyzing rates and patterns of consumption in developed and developing nations, this program targets overpopulation and exploitation of natural resources as the primary causes of the world's environmental problems and offers approaches to coping with them. (20 minutes, color)

Earth Revealed, Episode 1. Down to Earth
Annenberg/CPB
www.learner.org
Surface conditions of the planets Venus and Mars are compared with those of Earth, and scenes of Earth's living landscapes lead into a discussion of how unique Earth truly is. Major topics addressed in the series, including plate tectonics, natural resources, seismology, and erosion, are introduced in this program.

Earth revealed, Episode 10. Geologic Time
Annenberg/CPB
www.learner.org
To illustrate the immensity of geologic time, the entire span of Earth's existence is compressed down to a year. The timeline of major geologic events is superimposed onto the year for a condensed view of Earth's evolution. A relationship between this timeline and that of life on Earth is established, with fossils and radiocarbon dating playing a major role in the discovery.

Websites:

http://www.ipcc.ch/
http://cdiac.ornl.gov/
http://www.wmo.int/pages/prog/arep/gaw/ozone_2006/ozone_asst_report.html
http://www.epa.gov/ozone/defns.html#ozdepl
http://www.epa.gov/ozone/science/index.html
http://www.nas.nasa.gov/About/Education/Ozone/
http://www.epa.gov/ozone/
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