GE 302 - Industry and the Environment

Chapter I

Introduction to Environment, Ecosystems, Environmental Components, Natural Cycles, and Development

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(review Chapter 5 of the textbook for more information)

Environment:
It is all the conditions, circumstances, and influences surrounding, and affecting the development of an organism or group of organisms within the space they live in. This includes natural features; for example, mountains, trees, seas and oceans, air, water, energy, land, etc. and how the organism or groups of organisms interact with such features. *In summary, it is the sum of all external conditions affecting the life, development and survival of an organism.*

Environmental Components of the Earth:

1- Atmosphere: it is the gaseous envelope of air surrounding the earth to a height of approximately 1,000 km and mainly consists of 21% oxygen, 78% nitrogen, and 1% other gases, and rotates with the earth, because of gravity.
2- Hydrosphere: all the water on the surface of the earth, including oceans, seas, lakes, glaciers, etc. Water vapor, clouds, etc. may be considered part of the atmosphere or the hydrosphere.
3- Pedosphere: is the outermost layer of the earth that is composed of soil and subject to soil formation processes.

Ecology: is the science that deals with the relationship of living things to one another and their environment, or the study of such relationships.

Groups of interacting populations at a particular location comprise what is known as a community. Examples: consider the plant community of a tropical rainforest, the fish community of a freshwater lake, or the bird community of a saltwater marsh. Communities have many characteristics that are of interest to ecologists. One of the most important of these is the number of species present in a community or the species diversity of the community.

Ecosystem: It is the interacting system of a biological community and its non-living environmental surroundings.

In a given area, all populations (the community) and the physical environment comprise an ecosystem -- note that the ecosystem has both biotic and abiotic components.

biotic components are the living things that shape an ecosystem. They are, in entirety, any living component that affects another organism. Such things include animals which consume the organism in question, and the living food that the organism consumes. As opposed to abiotic components (non-living components of an organism's environment,

such as temperature, light, moisture, air currents, etc.), biotic components are the living components of an organism's environment, such as predators and prey.

Ecosystems are structured according to how different populations acquire energy -- species obtaining energy in a similar way are grouped into trophic levels -- there are three primary trophic levels:

1. primary producers

2. consumers

3. decomposers

Components of an ecosystem:

1- Non-living components: these include: air, water, soil, minerals, rocks, heat and light.
2- Living components: these include:
   a. Producers: autotrophic organisms capable of photosynthesis, they make food for themselves and indirectly for other components; these are primarily green plants. Plants convert inorganic substances; for example: Carbon dioxide CO_2, water and minerals into simple organic substances (carbohydrates and proteins) using solar energy; hence the plants grow in size.

$$CO_2 + H_2O \xrightarrow{\text{(light + chlorophyll)}} O_2 + \text{organic substance}$$

   b. Consumers: heterotrophic organisms dependent on other organisms for food, consumers can be subdivided into more specific trophic levels -- those feeding directly on producers are called primary consumers (herbivores) -- secondary and tertiary consumers (carnivores) eat other consumers.
   c. Decomposers: are organisms that obtain energy and nutrients from remains of dead producers and consumers; they are primarily bacteria and fungi and they are extremely important to the process of nutrient cycling (see natural cycles of phosphorous, nitrogen and carbon). Decomposers convert the organic substances into inorganic substances. Decomposers are classified according to their oxygen demand into: aerobic (needs oxygen to function), anaerobic (function in the absence of oxygen) and facultative (function in presence and absence of oxygen).

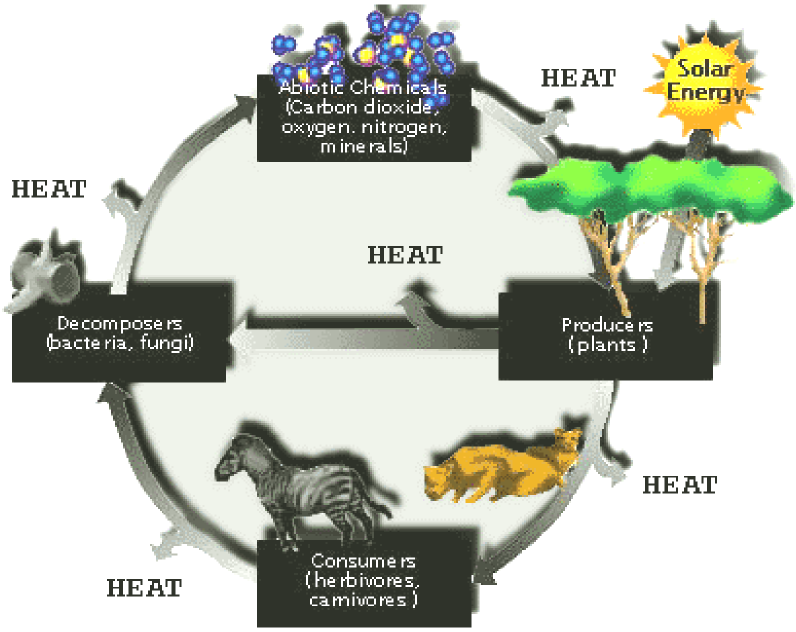
Biosphere: It is the portion of Earth and its atmosphere that can support life.

Biomass: All of the living material in a given area; often refers to vegetation.

Biodegradable: Capable of decomposing under natural conditions.

Biodiversity: Refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes.

Life Cycle and Energy & Nutrient Transfers



The Life Cycle of Our Earth Ecosystem

Ecosystems are structured -- can be viewed as a series of biotic components that are linked together and thus interact with one another.

The fact that ecosystem components are linked has an important ramification: disturbances to one component impact on all other components of the ecosystem to varying degrees.

Interactions between ecosystem components involve two general processes:

1. Energy flow.

2. Nutrient cycling.

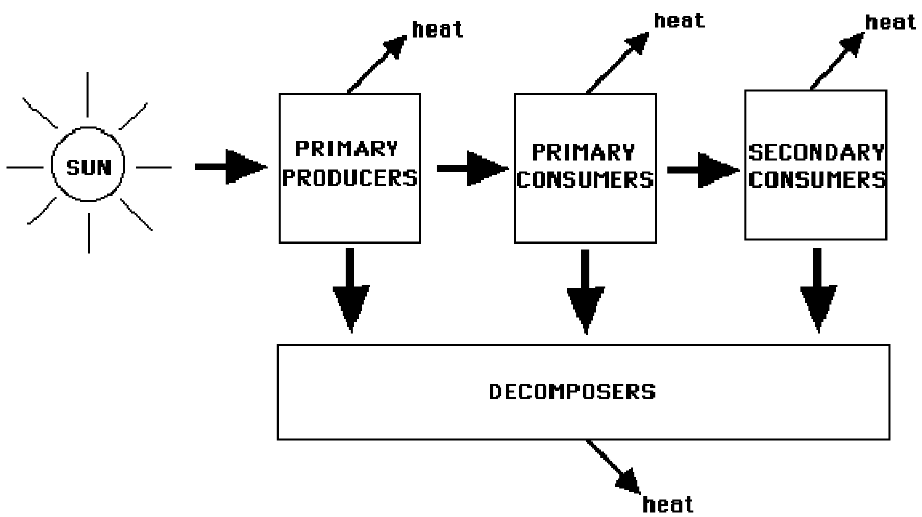
Energy Flow is a one-way process in ecosystems -- in order to persist, ecosystems require a constant input of energy.

1. the sun is the ultimate source of energy for most ecosystems.

2. primary producers capture a fraction of energy in sunlight striking the earth and convert it into chemical energy (carbohydrate) that is stored in tissues of the primary.

3. energy in tissues of primary producers transferred to consumers as each consumes tissue of other organisms -- about 90% - 95% of energy present in one component is lost as heat at each transfer -- very inefficient process -- very little energy left when decomposers get to it.

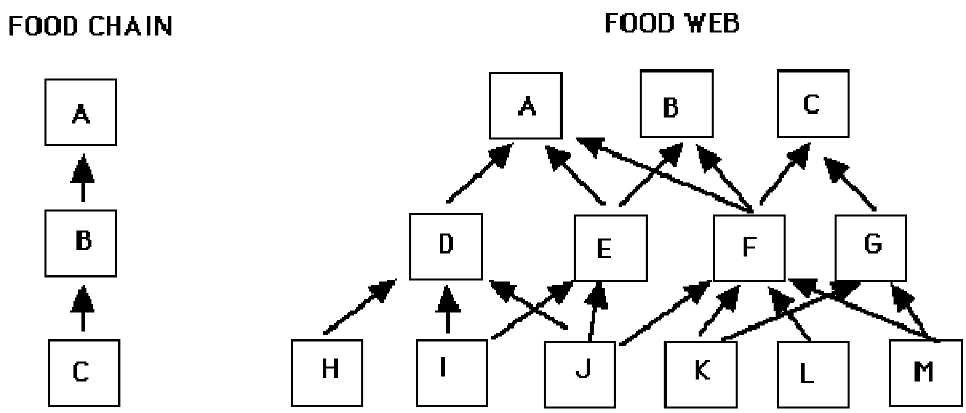
4. important point is that energy does not cycle through ecosystems -- ecosystems require constant energy input from sun or some other source.



The rate at which primary producers remove carbon from the atmosphere and convert it into biomass (living tissue) is called the primary productivity of the ecosystem -- productivity varies greatly from ecosystem to ecosystem -- here are some representative values:

Ecosystem	g C/ m^2 /year
tropical rainforest	2200
Grassland	600
Deserts	90
coral reefs	2500
lakes and streams	250
open ocean	125

Trophic relationships -- we can sometimes describe "who-eats-whom" in an ecosystem as a food chain -- more often, however, food chains are "cross-linked" into more complicated structures called food webs.



Notice that as the ecosystem diversity (e.g. number of species) increases, the complexity of these food webs also increases -- as complexity increases so does stability -- e.g. disturbance or extinction of one or two species can be compensated for -- in simple food webs or chains, extinction of one species may lead to the collapse of the entire system. Examples: Eskimos living mainly on fish and hunting of few polar animals are less stable than humans living around the equator living on more diverse ecosystems.

Natural Cycles of Major Elements in Our Ecosystem

1- Water (Hydrological Cycle)

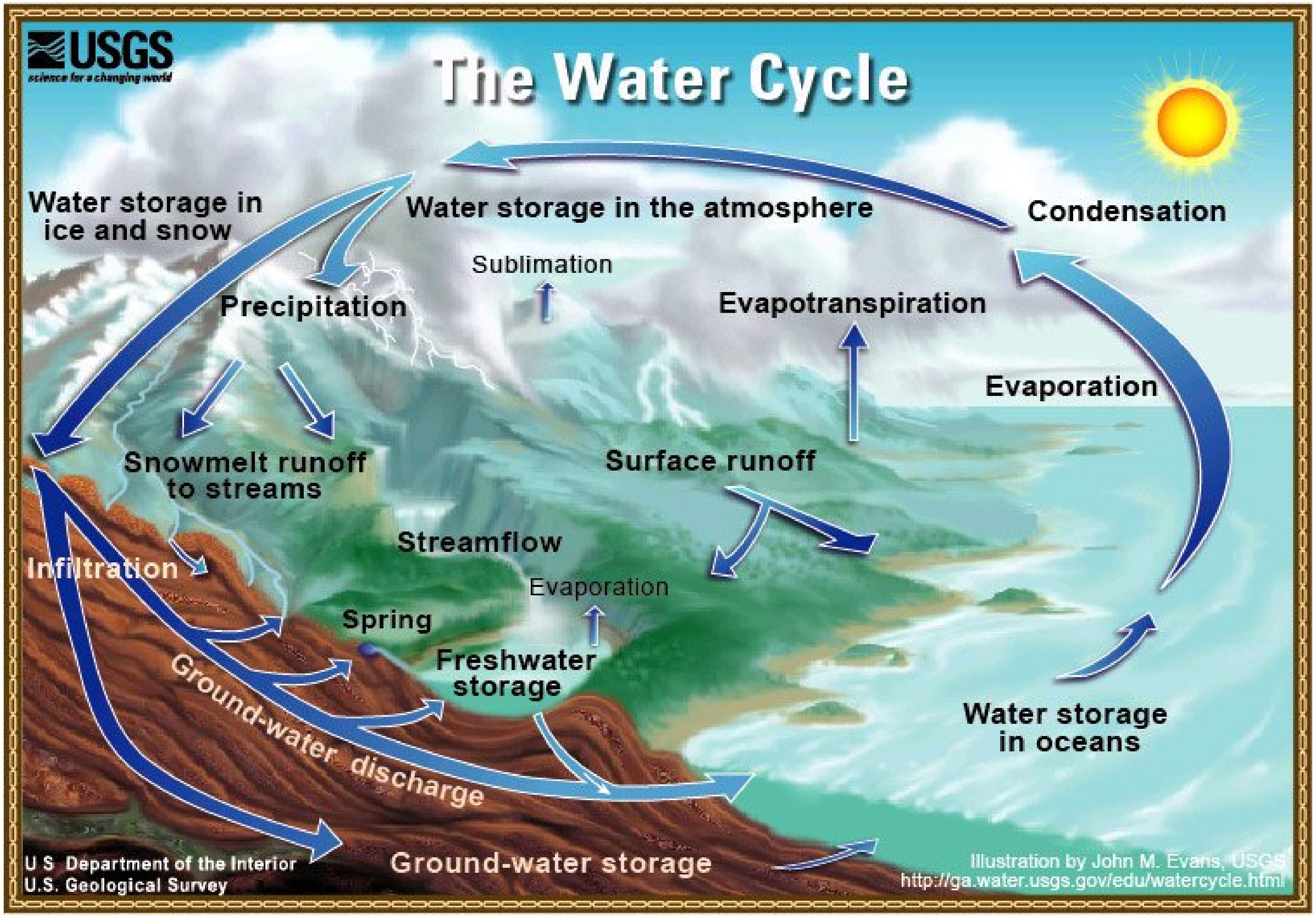
(see the figure on next page; source US Geological Survey (USGS) webpage)

(Review Section 7-1 in Chapter 7 of the textbook)

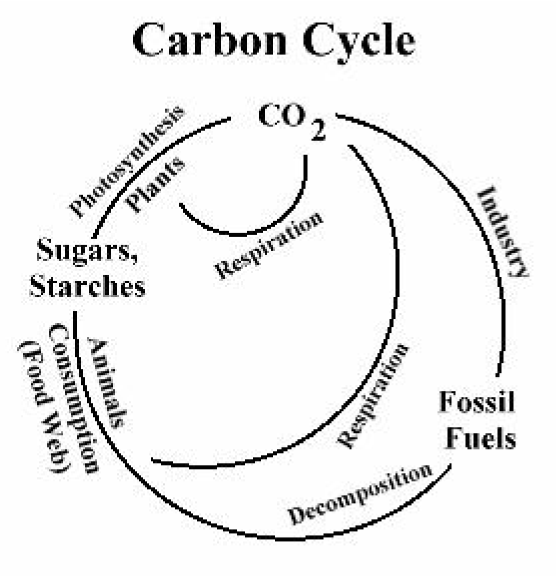
The water cycle describes the existence and movement of water on, in, and above the Earth. The water cycle has been working for billions of years and all life on Earth depends on it continuing to work.

The water cycle has no starting point. But, we'll begin in the oceans, since that is where most of Earth's water exists. The sun, which drives the water cycle, heats water in the oceans. Some of it evaporates as vapor into the air. Ice and snow can sublimate directly into water vapor. Rising air currents take the vapor up into the atmosphere, along with water from evapotranspiration, which is water transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe, cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snowpacks in warmer climates often thaw and melt when spring arrives, and the melted water flows overland as snowmelt.

Most precipitation falls back into the oceans or onto land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streamflow moving water towards the oceans. Runoff, and ground-water seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers, though. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers (saturated subsurface rock), which store huge amounts of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as ground-water discharge, and some ground water finds openings in the land surface and emerges as freshwater springs. Over time, though, all of this water keeps moving, some to reenter the ocean, where the water cycle "ends" or "begins" again.


USGS
science for a changing world
The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Snowmelt runoff to streams
Surface runoff
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
Ground-water storage
U S Department of the Interior
U.S. Geological Survey
Illustration by John M. Evans, USGS
http://ga.water.usgs.gov/edu/watercycle.html

2- **Carbon Cycle (C-Cycle) (For this and the following cycles, review Section 5-4 in Chapter 5 of the textbook for more details)**



Organic chemicals are made from carbon more than any other atom, so the Carbon Cycle is a very important one. Carbon between the biological to the physical environment as it moves through the carbon cycle.

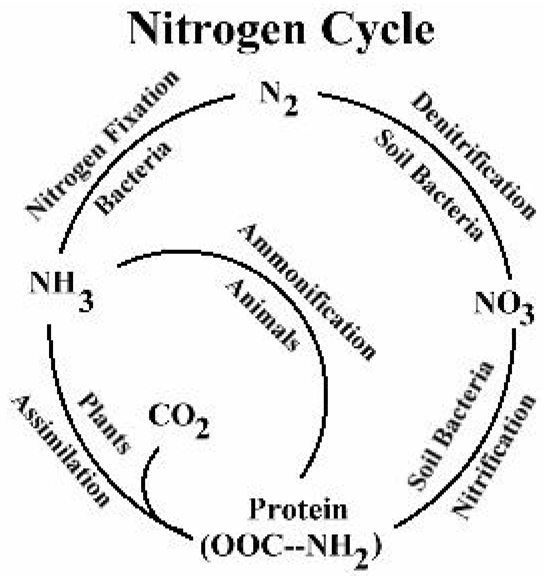
Earth's atmosphere contains 0.035% carbon dioxide, CO_2, and the biological environment depends upon plants to pull carbon into sugars, proteins, and fats. Using photosynthesis, plants use sunlight to bind carbon to glucose, releasing oxygen (O_2)in the process. Through other metabolic processes, plants may convert glucose to other sugars, proteins, or fats. Animals obtain their carbon by eating and digesting plants, so carbon moves through the biotic environment through the trophic system. Herbivore eat plants, but are themselves eaten by carnivores.

Carbon returns to the physical environment in a number of ways. Both plants and animals respire, so they release CO_2 during respiration. Luckily for animals, plants just happen to consume more CO_2 through photosynthesis than they can produce. Another route of CO_2 back to the physical environment occurs through the death of plants and animals. When organisms die, decomposers consume their bodies. In the process, some of the carbon returns to the physical environment by way of fossilization. Some of it remains in the biological environment as other organisms eat the decomposers. But by far, most of the carbon returns to the physical environment through the respiration of CO_2.

Source: http://www.starsandseas.com

Review "Global Warming"

3- **Nitrogen Cycle (N-Cycle)**



Proteins, nucleic acids, and other organic chemicals contain nitrogen, so nitrogen is a very important atom in biological organisms. Nitrogen makes up 79% of Earth's atmosphere, but most organisms can not use nitrogen gas (N_2). N_2 enters the trophic system through a process called **nitrogen fixation**. Bacteria found on the roots of some plants can fix N_2 to organic molecules, making proteins. Again, animals get their nitrogen by eating plants. But after this point, the nitrogen cycle gets far more complicated than the carbon cycle.

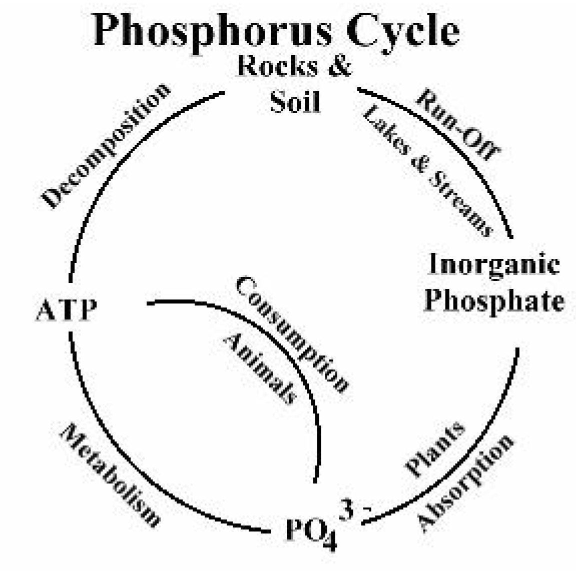
Animals releases nitrogen in their urine. Fish releases NH_3, but NH_3 when concentrated, is poisonous to living organisms. So organisms must dilute NH_3 with a lot of water. Living in water, fish have no problem with this requirements, but terrestrial animals have problems. They convert NH3 into urine, or another chemical that is not as poisonous as NH3. The process of releases NH_3 is called **ammonification**.

Because NH3 is poisonous, most of the NH_3 which is released is untouchable. But soil bacteria have the ability to assimilate NH_3 into proteins. These bacteria effectively eats the NH_3, and make proteins from it. This process is called **assimilation**.

Some soil bacteria does not convert NH_3 into proteins, but they make nitrate NO_3^- instead. This process is called **nitrification**. Some plants can use NO_3^-, consuming nitrate and making proteins. Some soil bacteria, however, takes NO_3^-, and converts it into N_2, returning nitrogen gas back into the atmosphere. This last process is called **denitrification**, because it breaks nitrate apart.

Source: http://www.starsandseas.com

4- Phosphorus Cycle **(P-Cycle)** **(** Source: http://www.starsandseas.com)



Phosphorus is the key to energy in living organisms, for it is phosphorus that moves energy between molecules, driving an enzymatic reaction, or cellular transport. Phosphorus is also the glue that holds (di-nucleic acid) DNA together, binding sugars together, forming the backbone of the DNA molecule.

Again, the keystone of getting phosphorus into trophic systems are plants. Plants absorb phosphorous from water and soil into their tissues, tying them to organic molecules. Once taken up by plants, phosphorus is available for animals when they consume the plants.

When plants and animals die, bacteria decomposes their bodies, releasing some of the phosphorus back into the soil. Once in the soil, phosphorous can be moved 100s to 1,000s of miles from were they were released by riding through streams and rivers. So the water cycle plays a key role of moving phosphorus from ecosystem to ecosystem.

In some cases, phosphorous will travel to a lake, and settle on the bottom. There, it may turn into sedimentary rocks, limestone, to be released millions of years later. So sedimentary rocks acts like a back, conserving much of the phosphorus for future eons.

Eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants weeds). This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die. Nutrients can come from many sources, such as fertilizers applied to agricultural fields, golf courses, and suburban lawns; deposition of nitrogen from the atmosphere; erosion of soil containing nutrients; and sewage treatment plant discharges. Water with a low concentration of dissolved oxygen is called hypoxic.

Development and the Environment

Development is to use and adapt our surrounding environment and its natural and human resources, effects and material and moral conditions and to utilize them for serving humans and their material and moral needs. Examples: First humans using leaves to cover their bodies; fishing, swimming and diving in water bodies and building ships.

Sustainable Development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations. (Examples: German efforts to maintain the forests; preserving fish species; e.g. salmon fish in Canada.)

Environment and development in all of its forms (social, agricultural, industrial, human, economic and cultural) are closely linked, so that development cannot go on degraded environmental resource base. Examples: forest overharvesting and excessive groundwater withdrawal from wells.

Sustainable Economy: is one that produces wealth and provides jobs for many human generations without degradation the environment.

Fundamentals of Sustainability:

1- Reduction in society's use of nonrenewable natural sources,
2- In the long term, solution must be market based: it is more effective and cost effective for society to provide incentive to use alternatives or reduce the use of coal, gasoline, and other substances whose use results in pollution than to pass laws specifying how much pollution may be emitted.

Renewable Resources:
Are those that can be replaced within a few human generations.

Nonrenewable Resources:
Are those that are replaceable only in geological time scale.

Sustainable Energy Sources: often called Renewable Sources

Hydropower, biomass or biofuels, geothermal, wave (or tides), wind, hydrogen, and solar energy.

Biofuels and wind energy now provide only 6% of the world's energy. They are growing at annual rates of 17 to 29%.

Biofuels from biomass: biomass energy includes wastes (include wood scrps, pulp and paper scrapes and municipal solid wastes including animal wastes), standing forests, and energy crops.

Geothermal: tap the natural heat from earth's magma. Energy may be used directly to heat buildings or to produce electricity from vented steam or by heating water to produce steam.

Pollution

Any change in the physical, chemical or biological properties of the main constituents of the environment (air, land and water) that affects the living organisms adversely.

Major Factors Leading to Increasing Pollution (of Human Type)

1. Population growth

2. Industry

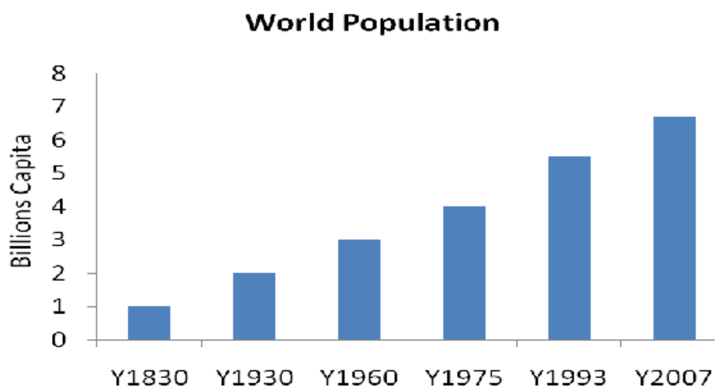
3. Increased Energy Consumption

4. Wars

1- Population growth

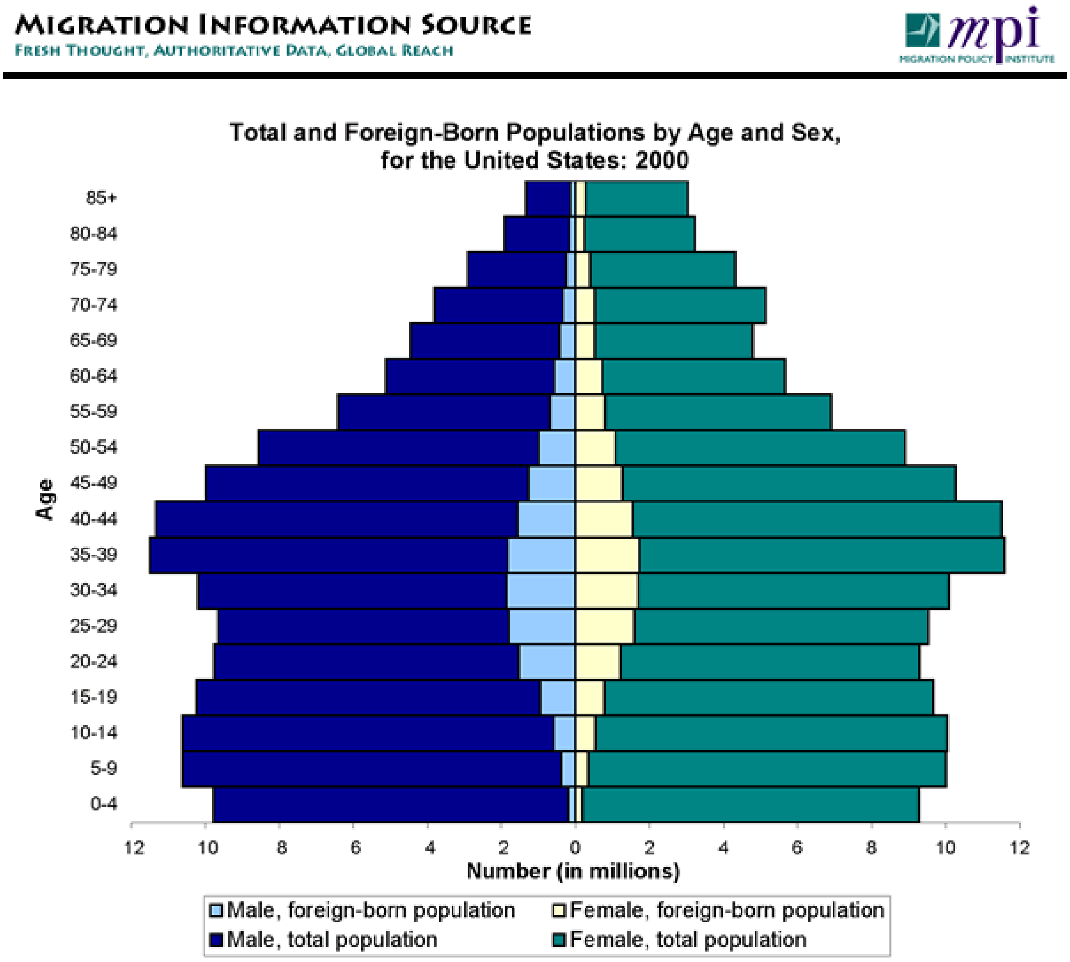
Year	World Population in Billions
1830	1
1930	2
1960	3
1975	4
1993	5.5
2007	6.7

Saudi Arabia's population in 2006 is ≈ 27.5 millions.



The Population Pyramid

It is simply a representation of the human structure of a country/continent by age group and gender.



Total population: 281,421,906. Foreign-born population: 31,107,889. Source: Census 2000, 1% Public Use Micro-Sample Data.

Factors affecting the shape of the pyramid include: rates of births and deaths, wars, immigration and migration, health care, epidemic diseases, etc...

2. Industry

- Light industry; e.g. food industry, plastics, textile, etc.
- Heavy industry; e.g. weapons, construction, nuclear reactors, etc.

3. Increased Energy Consumption

- Non-renewable energy sources (traditional): fossil fuels: oil, natural gas, coal

- Renewable energy sources: solar, wind, water power (hydropower), tidal power

- Oil is considered the most important source of energy as its consumption rate is forms more than 40% of the total energy consumed

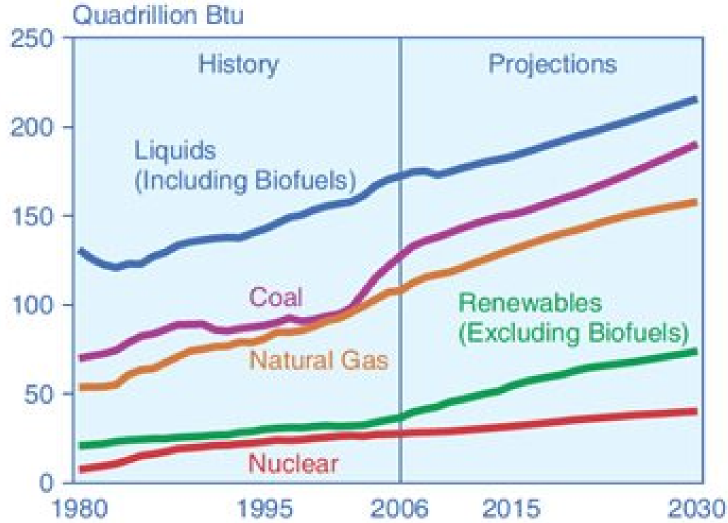
- The annual energy consumption has increased tenfold in the 20th century

(see Figures 14, 15 next page)

4. Wars

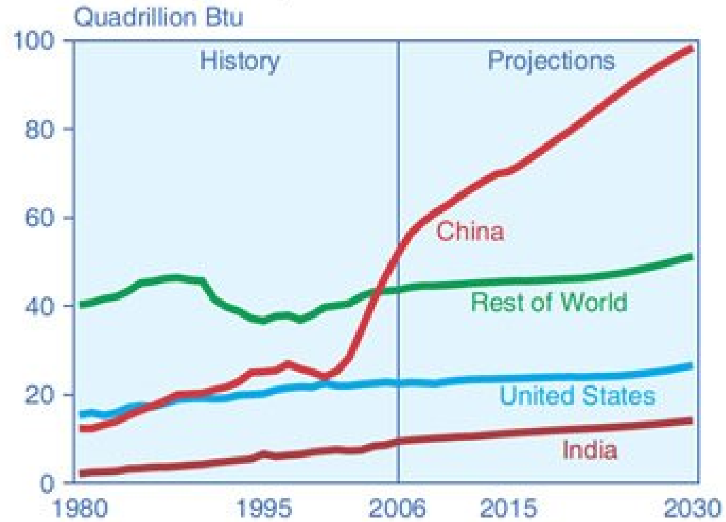
- Cold war versus field war
- Short term / long term
- Small scale (Iran/Iraq, Palestine/Israel) versus large scale (World Wars I and II)

Figure 14. World Marketed Energy Use by Fuel Type, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Figure 15. Coal Consumption in Selected World Regions, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).