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

**Ecology:** is the science that deals with the relationship of living things to one another and with their environment.

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.

**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.

## 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. The ecosystem also can be described simply as the collection of all living and non-living components in a particular area. All living components of an ecosystem are called biotic components. The non-living components of the ecosystem are called abiotic components.

**1-Biotic components** are all living things belong to different species and shape an ecosystem in associated and interrelated populations. These components include plants, animals and all other organisms in the ecosystem. The biotic components are the living components of an organism's environment, such as predators and prey.

**2-Abiotic components** are non-living components of an organism's environment, such as temperature, light, moisture, air currents, etc. The abiotic components are broadly classified under three categories.

- Climatic components which include the climatic regime and physical factors of the environment like light, humidity, atmospheric temperature, wind, etc.
- Edaphic components which are related to the structure and composition of soil including its physical and chemical properties.
- Inorganic components like water, carbon, sulphur, nitrogen, phosphorus and so on. Organic substances like proteins, lipids, carbohydrates, humic substances etc.

Ecosystems are structured to 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.

The interactions between ecosystem components involve two general processes:

1. Energy flow.

2. Nutrient cycling.

Ecosystems are structured according to how different populations acquire energy and nutrients; species obtaining energy in a similar way are grouped into **trophic levels**. The **trophic level** of an organism is the position it occupies in a food chain. It is also defined as the feeding level of an organism in its community. There are three trophic levels.

a. Primary producers b. Consumers c. Decomposers

## 1. Energy Flow

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

- The sun is the ultimate source of energy for most ecosystems.

- 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.

- 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.

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

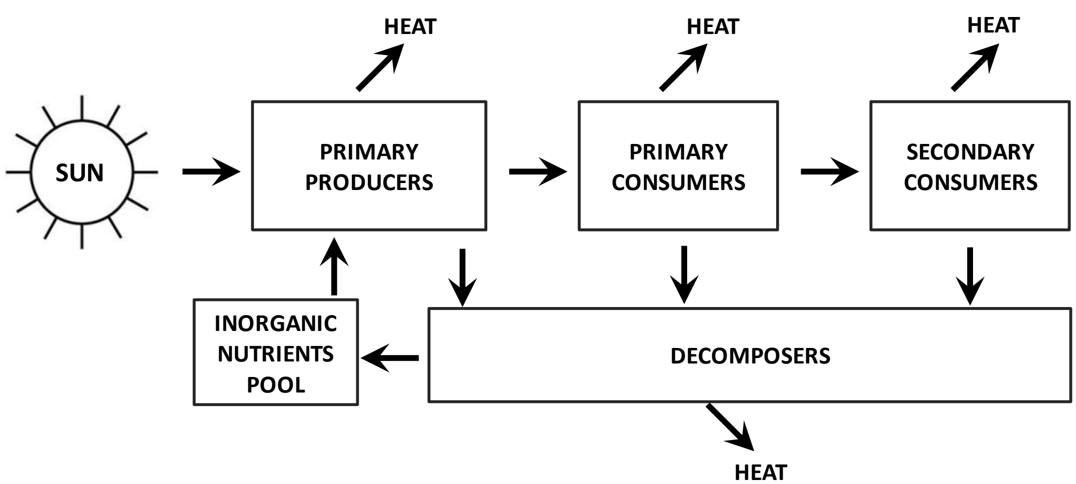



Figure 1-1: Energy and nutrients transfer through ecosystems

## 2. Nutrient Transfer

a) Producers: autotrophic organisms (autotroph-autotrophs) 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.

| | | | | | | |
|---|---|---|---|---|---|---|
| $CO_2$ | + | $H_2O$ | $\xrightarrow{\text{Light}}$ | $C_6H_{12}O_6$ | + | $6O_2$ |
| Carbon dioxide | + | water | chlorophyll | Sugar | + | Oxygen |
| | | | | Organic matter biomass | | |

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

**Primary productivity:** 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. The gross primary productivity is the total amount of organic matter that is produced through photosynthesis. The net primary productivity describes the amount of energy (organic matter) that is remains available for plant after subtracting the fraction that is used for respiration. Primary productivity varies greatly from ecosystem to ecosystem according to temperature, moisture and other factors. Here are some representative values:

**Table 1-1: Typical values of primary productivities at different ecosystems**

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

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. Omnivores the organisms that can eat plants and animals.

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).

**Biodegradable:** Capable of decomposing under natural conditions.

## Life Cycle and Energy & Nutrient Transfers

The life cycle of our earth ecosystem is presented below in Figure 1-2.

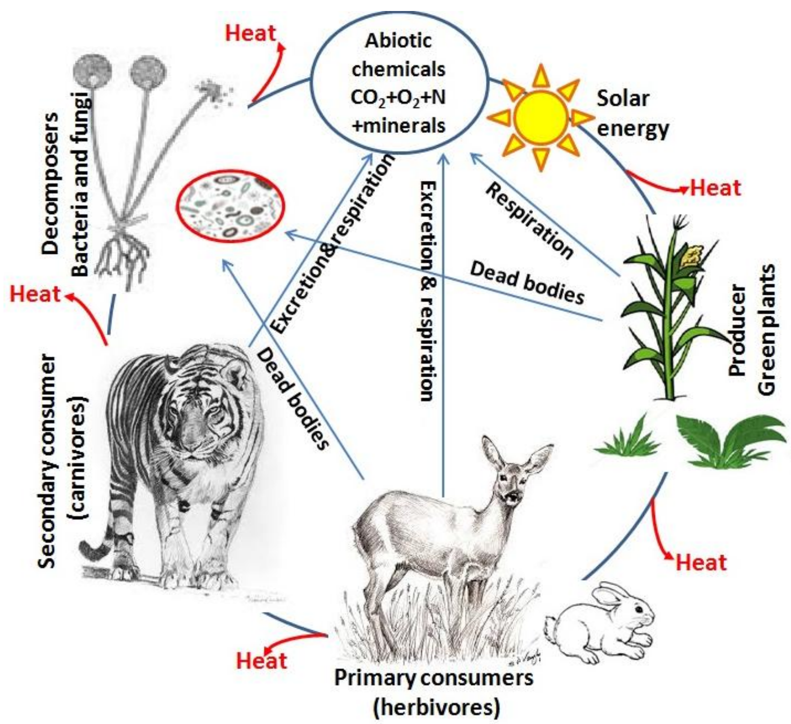



Figure 1-2: The life cycle of our earth ecosystem

**<u>Trophic relationships.</u>** The feeding relationships between different organisms in an ecosystem are called tropic relationships. A **food chain** is a linear sequence of links between organisms, starting from a species that are called producers and ends at a species that is called decomposers. The food chain shows "who eats whom" in an ecosystem. Any food chain goes through a series of linear relationships starting from primary producers then primary consumers, then secondary consumers and so on. These feeding levels as previously mentioned are called trophic levels. All producers belong to first trophic level, all primary consumers belong to second trophic level, all secondary consumers belong to third trophic level and so forth. Food chains seldom exist as isolated entities. All food chains are interconnected or cross-linked into more complicated structures called "**the food webs**"

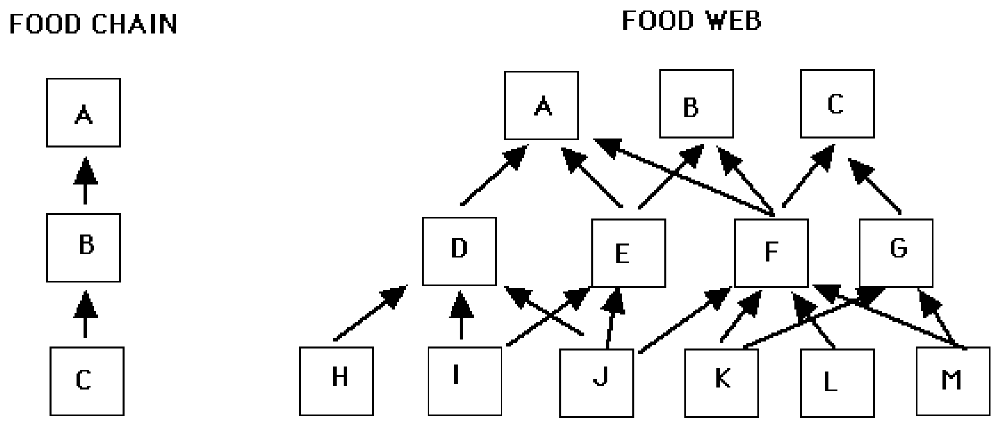



Figure 1-2: schematic diagram shows food chain and food web

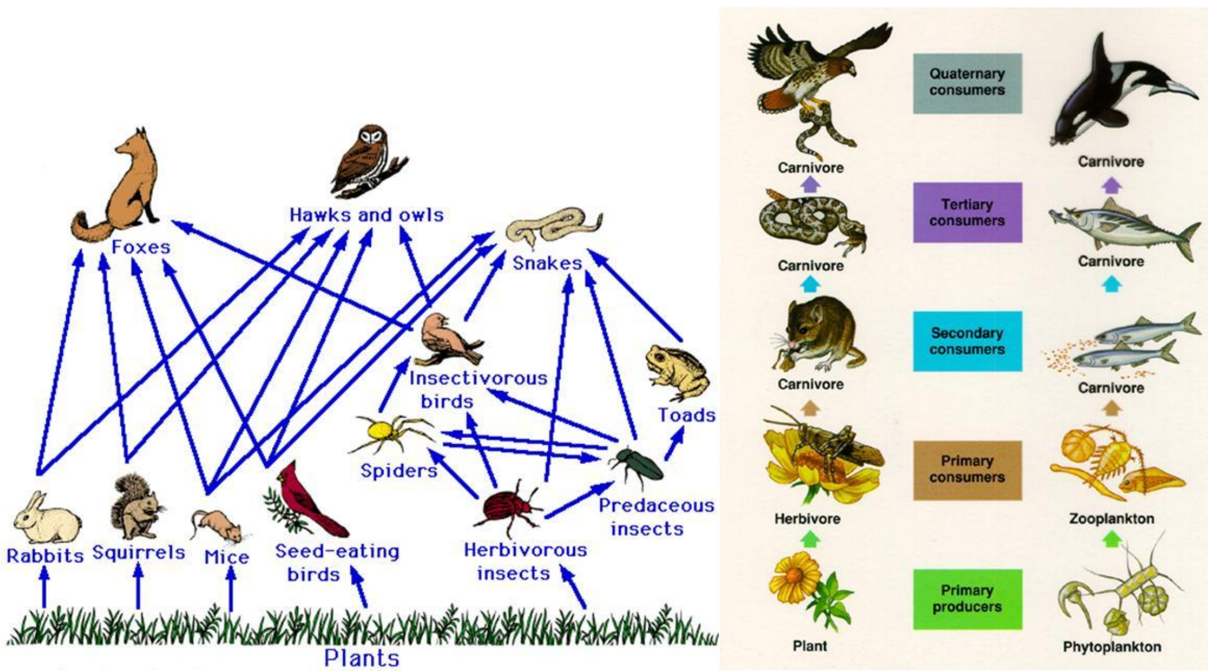



Figure 1-3: drawing examples of food chains and food web

In an ecosystem, when the number of species increases (ecosystem diversity) increase, the complexity of the food webs increase. Increasing the complexity of the ecosystem (food webs) increases the stability of the ecosystem. In complex ecosystems, disturbance or extinction of one or two species can be compensated for while 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)**

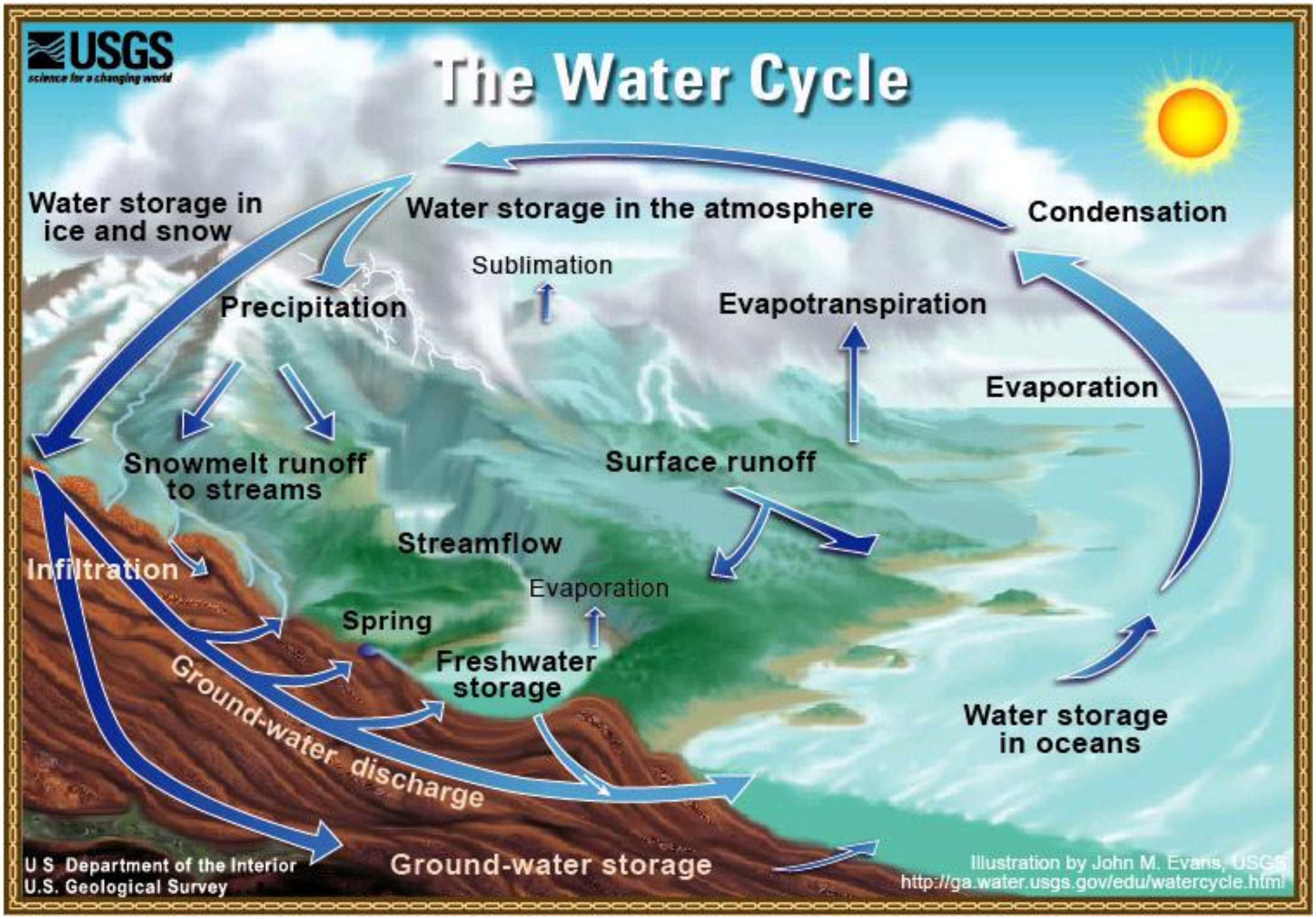
(see the figure on next page; source US Geological Survey (USGS) webpage)

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

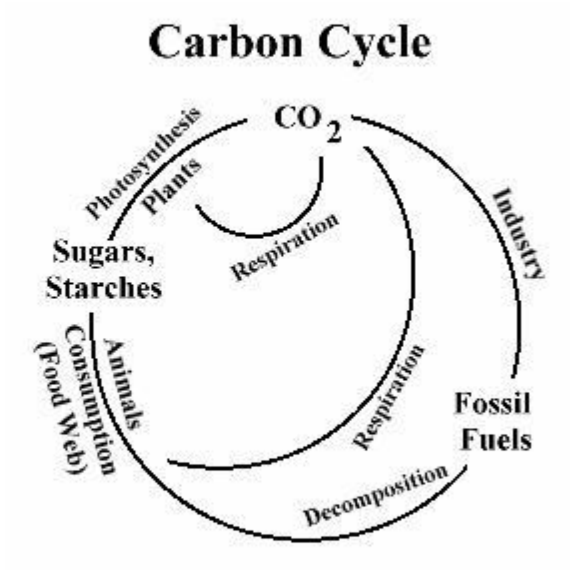
The water cycle describes the existence and movement of water on, in, and above the Earth. The water cycle has been working for billions of years and all life on Earth depends on it continuing to work.

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)**



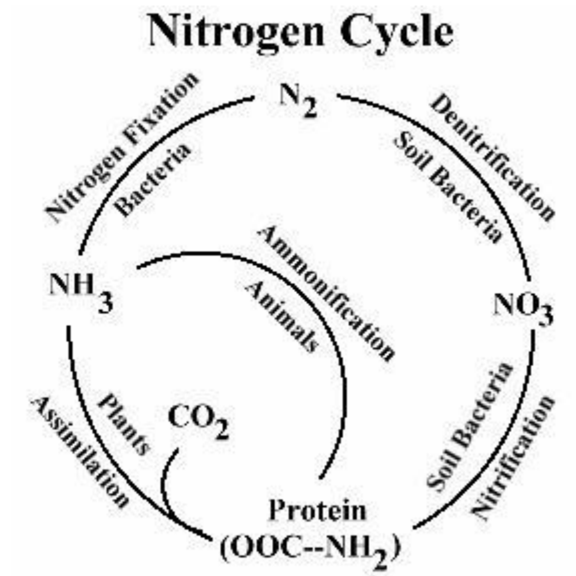

Organic chemicals are made from carbon more than any other atom, so the Carbon Cycle is a very important one. Carbon between the biological to the physical environment as it moves through the carbon cycle.

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 eats 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 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. Under normal conditions, died bodies of plants and animals are biodegraded by decomposers and return back to inorganic forms (carbon dioxide, water and other gases) with release of heat. Under abnormal conditions of temperature and pressure, died bodies of living things convert to petrol and charcoal (fossil fuels). Some of carbon remains in the biological environment (decomposers) 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

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




Nitrogen cycle gets far more complicated than the carbon 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 **biological 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. Nitrogen fixation occurs also by physical or natural process through lightening and by artificial or industrial (Haber process at 200 atm and 400 $^oC$) nitrogen fixation.

Animals releases nitrogen as urea and uric acid 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 these requirements, but terrestrial animals have problems. They convert NH3 into urine, or another chemical that is not as poisonous as $NH_3$. The process of releases $NH_3$ is called **ammonification**.

Specific types of bacteria that are present everywhere in soil and water have the ability to assimilate $NH_3$ into proteins. These bacteria effectively absorb ammonia and convert it into (organic nitrogen) in a process called nitrogen **assimilation**. Other species like blue green algae have the ability to fix nitrogen into protein as well.

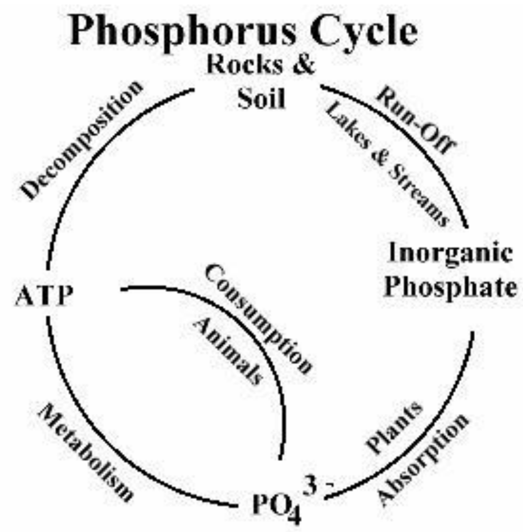
Other bacteria do not convert ammonia into protein but instead oxidise ammonia into nitrite and nitrate through **nitrification** process. Nitrification is two step process; oxidation of ammonia into nitrite by ammonia oxidisers and oxidation of nitrite into nitrate by nitrite oxidisers. Nitrate in soil and other ecosystem either absorbed by plants and converted to plant protein or absorbed by other types of bacteria and converted into nitrogen gas ($N_2$), returning nitrogen gas back into the atmosphere. This process is called **denitrification** and bacteria that are doing the job are called denitrifying bacteria. Source: http://www.starsandseas.com

**Table 1-2: Different processes of nitrogen fixation**

| Non-biological | | Biological | |
|---|---|---|---|
| Industrial | 50 million ton/year | Agricultural lands | 90 million ton/year |
| Combustion | 20 million ton/year | Forest and non agricultural lands | 50 million ton/year |
| Lightning | 10 million ton/year | Seas | 35 million ton/year |
| Total | 80 million ton/year | Total | 175 million ton/year |

Data from various sources, compiled by DF Bezdicek & AC Kennedy, in *Microorganisms in Action* (eds. JM Lynch & JE Hobbie). Blackwell Scientific Publications 1998.

**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 is 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 decompose 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 act 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 growth of algae or phytoplankton (algae blooms). This algae bloom reduces dissolved oxygen in the water during night and after dying and its decomposition consume more oxygen and makes water hypoxic (water with low concentration of dissolved oxygen). Hyperoxic water is the water with high concentration of oxygen. Excessive nutrients 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 effluent or discharge of sewage treatment plants.

**Development and the Environment**

*Development:* Is the use, adapt and utilization of natural and human resources, effects, and material and moral conditions in the surrounding environment for serving humans and their material and moral needs.

***Sustainable Development*** Is the d*evelopment that meets the needs of the present without compromising the ability of future generations to meet their own needs*. (Examples: German efforts to maintain the forests; preserving fish species; e.g. salmon fish in Canada.). New concept of sustainable development has three components: environment, society, and economy. The well-being of these three areas is intertwined, not separate. So the UNESCO promotes sustainable international resource development that is socially desirable, economically viable, culturally appropriate and ecologically sustainable.

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. Sustainable Economy: is one that produces wealth and provides jobs for many human generations without degradation of 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: r**esources that can be replaced within a few human generations.

**Non-renewable Resources: r**esources that are replaceable in geological time scale.

**Sustainable Energy Sources:** often called Renewable Sources

- Hydropower, biomass or bio-fuels, geothermal, wave (or tides), wind, hydrogen, and solar energy.
- Bio-fuels and wind energy now provide only 6% of the world's energy and are growing at annual rates of 17 to 29%.
- Bio-fuels from biomass: biomass energy includes wastes (wood and paper scraps and municipal solid wastes), standing forests, and energy crops.
- Geothermal: tap the natural earth internal heat (Earth's magma). Energy can be used directly to heat buildings or be used to produce electricity from vented steam or by heating water to produce steam.

# Pollution

**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 (Human type)

*1. Population growth*

*2. Industry*

*3. Increased Energy Consumption*

*4. Wars*

1- ***Population growth***

Changes in population growth and composition, including aging and urbanization, could significantly affect global emissions of carbon dioxide and other pollutants. Developing nation which tends to be younger and have more population will increase its ecological demands on the climate faster.

**Population pyramid = age pyramid or age picture diagram**

- It is a graphical illustration that shows the distribution of various age groups in a population (typically that of a country or region of the world), which forms the shape of a pyramid when the population is growing.
- It is often viewed as the most effective way to graphically depict the age and sex distribution of a population, partly because of the very clear image these pyramids present
- Factors affecting shape of population pyramid includes rates of birth and death, wars, immigration and migration, health care, epidemic diseases etc.

**Population pyramid could be one of the following:**

**Expansive population pyramid:** which is characterized by or shows larger number or percentages of younger people (rapid population growth)

**Constrictive population pyramid:** which is characterized or shows low number or percentages of younger people (negative population growth)

**Stationary or near stationary population pyramid:** displays somewhat equal numbers or percentages for almost all age groups. (Population growth is neutral or stable)

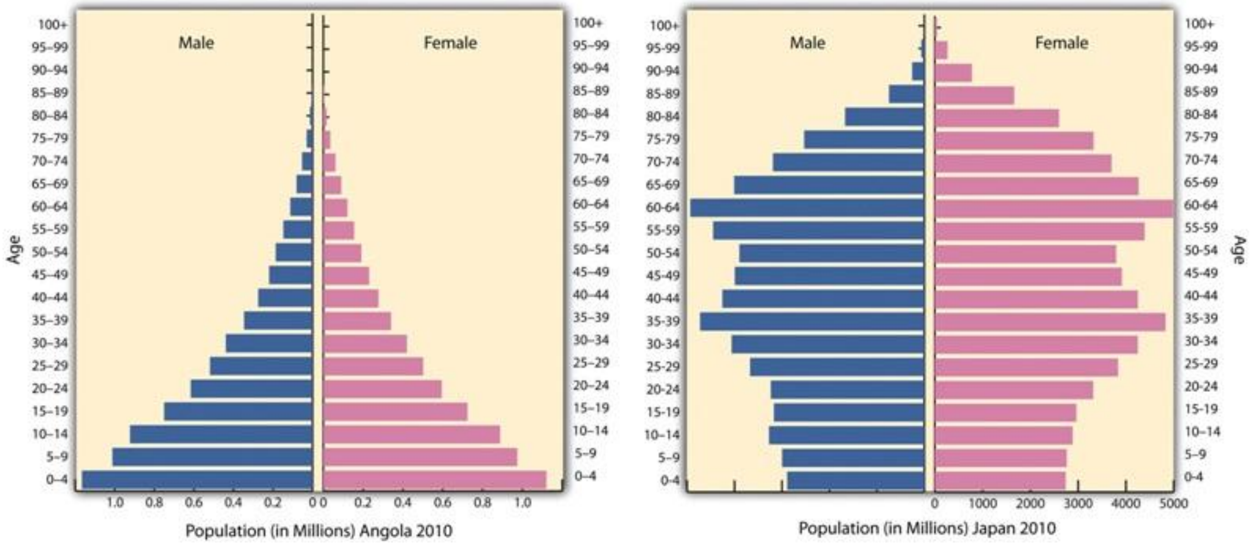



**Figure 1-8: showing different pattern of population pyramid**

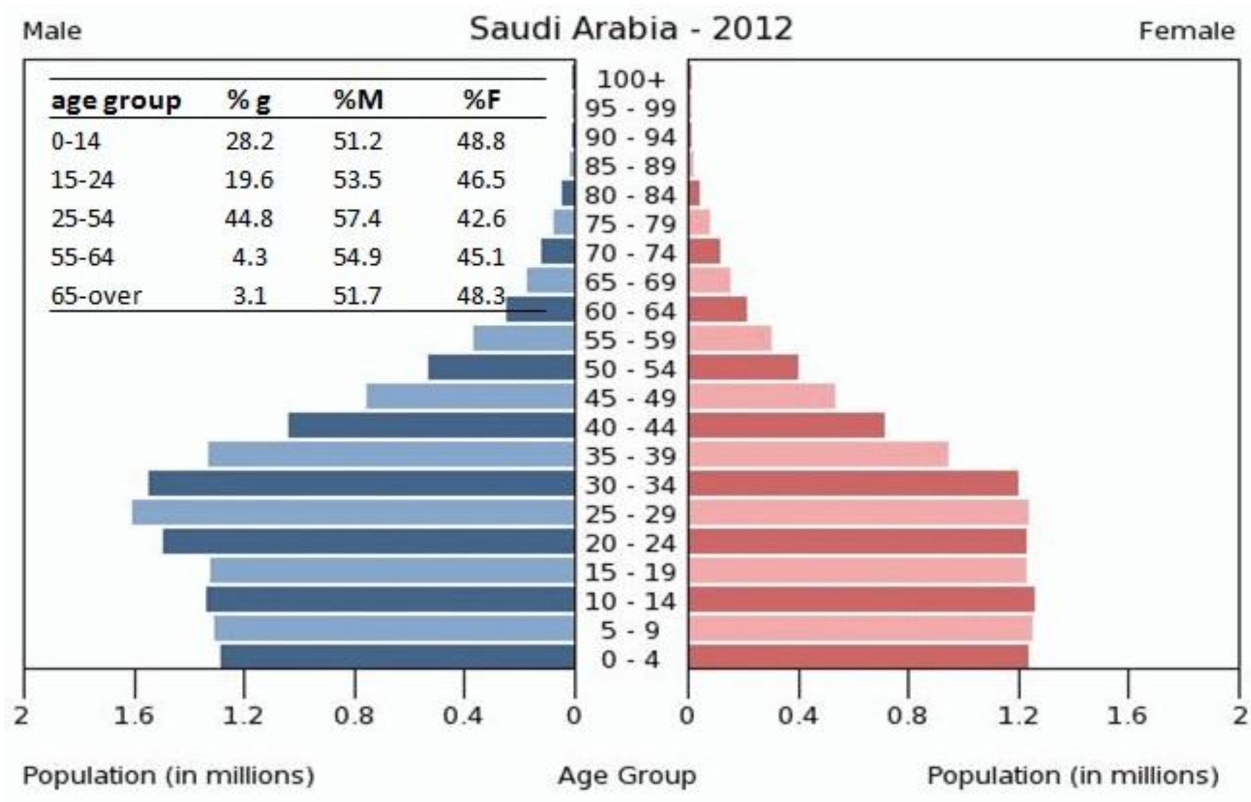



**Figure 1-9: Showing population pyramid of Saudi Arabia**

### *2. Industry*

- ☐ **Light industry**

- ✓ Is usually less capital intensive
- ✓ Is more consumer oriented than business oriented or end user industry rather than intermediates for use by other industry
- ✓ Light industries require only a small amount of raw materials, area and power Have less environmental impacts than those associated with heavy industry
- ✓ Zoning laws are more likely to permit light industry near residential areas
- ✓ The value of the goods is low and they are easy to transport.
- ✓ It is the production of small consumer goods
- ✓ Some light industry can cause significant pollution or risk of contamination as electronics which can create potentially harmful levels of lead or chemical wastes due to improper handling of solder and waste products (such as cleaning and degreasing agents used in manufacture)
- ✓ Examples: food, plastic, textile, shoes, furniture, consumer electronics and home appliances industry, etc.

☐ **Heavy industry**

- ✓ The heavy industry projects can be generalized as more capital intensive or as requiring greater or more advanced resources, facilities or management.
- ✓ It can mean production of products which are either heavy in weight or in the processes leading to their production.
- ✓ Example projects include the construction of large buildings, chemical plants, the aerospace rockets, also includes the production of construction equipment such as cranes and bulldozers.
- ✓ Other examples are weapons, construction, nuclear reactors, ship building, automotives, 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

### *4. Wars*

The wars can cause the following impacts on the environment:

1. Render land unusable for further use
2. Make access across the lands dangerous or fatal
3. Pollution with chemical weapons (use of Agent Orange by US army in Vietnam)
4. Atomic bombing (as in Japan)
5. Depleted uranium use (as in Iraq)
6. Oil fires (as in Kuwaiti oil fires during the Kuwait liberation war)
7. Fossil fuel use
8. River floods, 1938 yellow river flood
9. Power station oil spill, Lebanon 2006

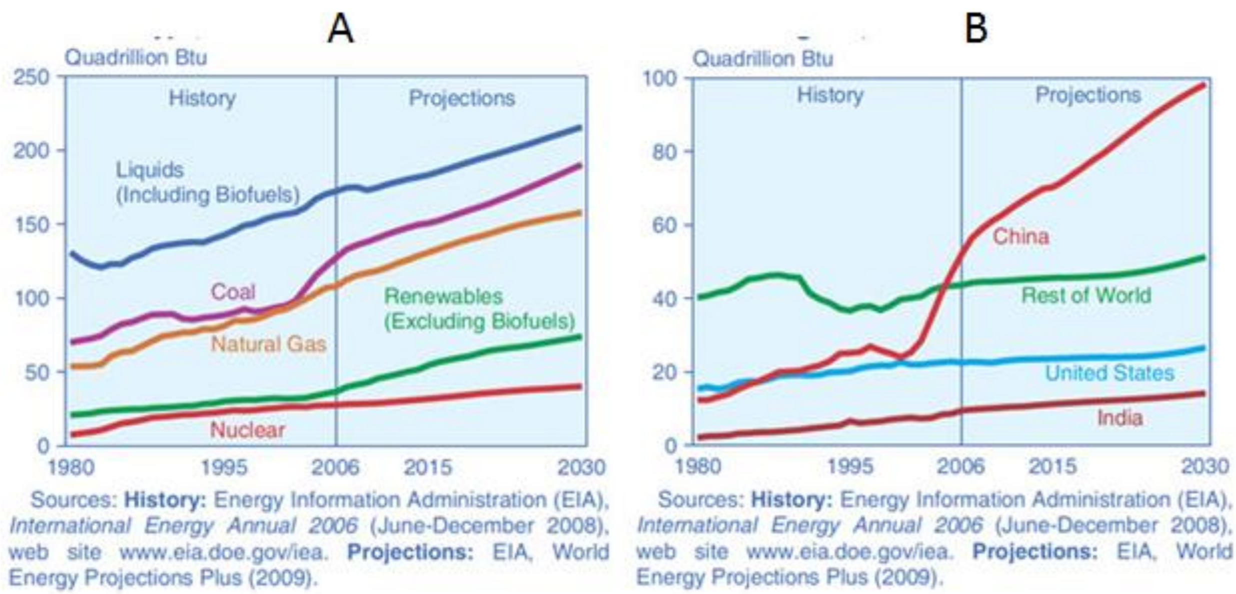



Figure 1-10: World market energy use (recorded and predicted by Fuel type (A) and coal consumption in selected world regions (B); 1980-2030