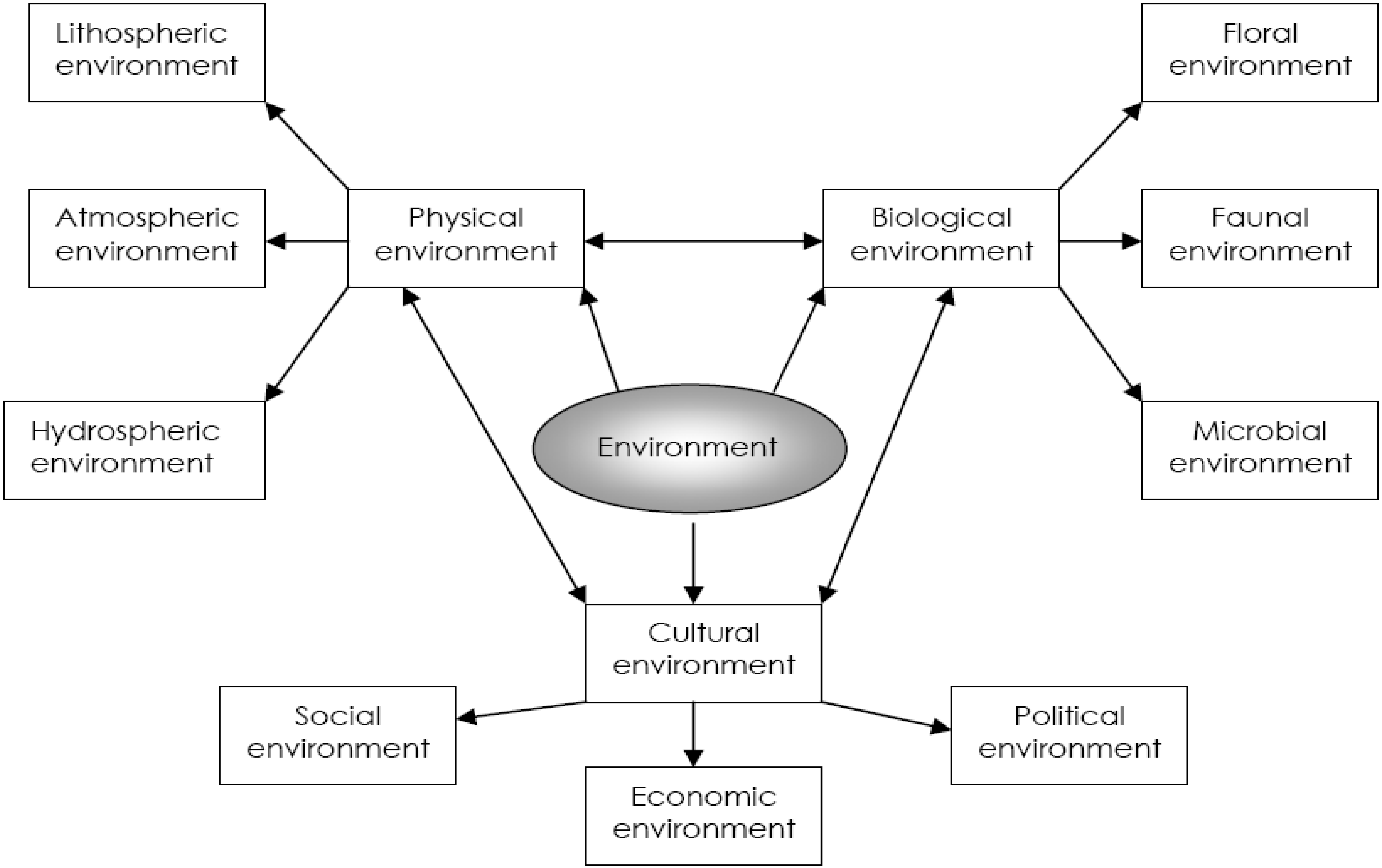
CHAPTER 2
CONCEPTS OF ECOLOGY AND NATURAL RESOURCES

Introduction

- all that environs (surrounds) us
  1. recreation and aesthetics
  2. source of natural resources
  3. sink for wastes produced by human activities.
- These days it loses its ability to discharge these functions properly due to stress from man-made activities
- Environment has multi-dimensional aspects—the perception varies

Environment component Interaction

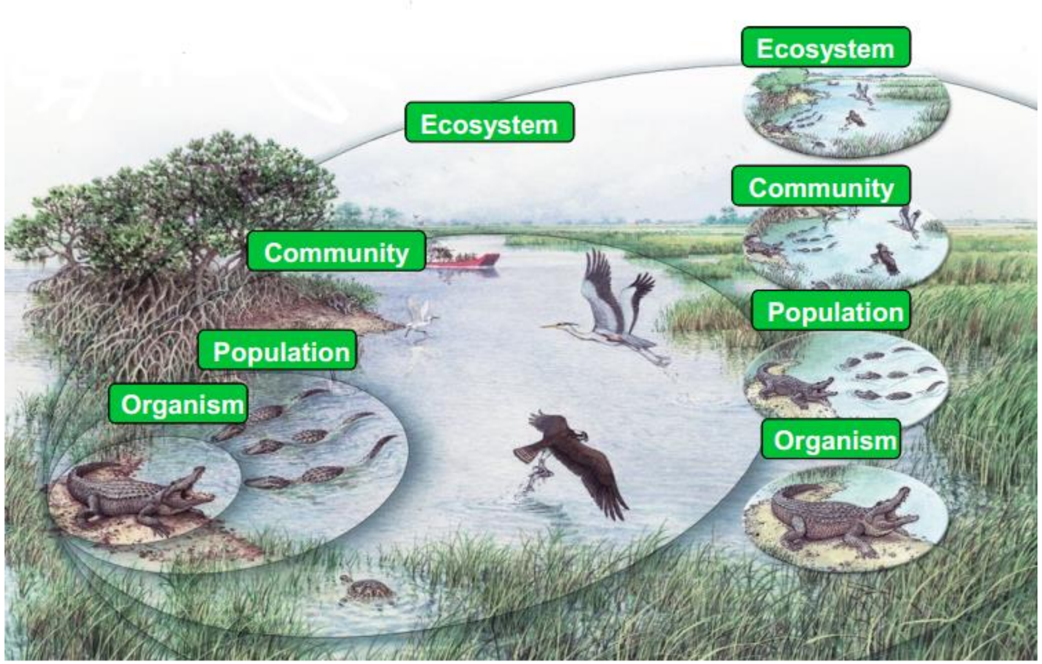


Ecosystem

- *Ecology can be defined as a scientific study of the relationships of living organisms with each other and with their environment*
  - assessing the changes occurring in a lake or river when untreated sewage is added to it.
  - Evaluating the likely consequences of construction of dams or diversion of rivers on aquatic lives
  - Investigation into the ecosystem of water supply sources
  - Investigation into the chemistry of solids to which a particular plant species is restricted

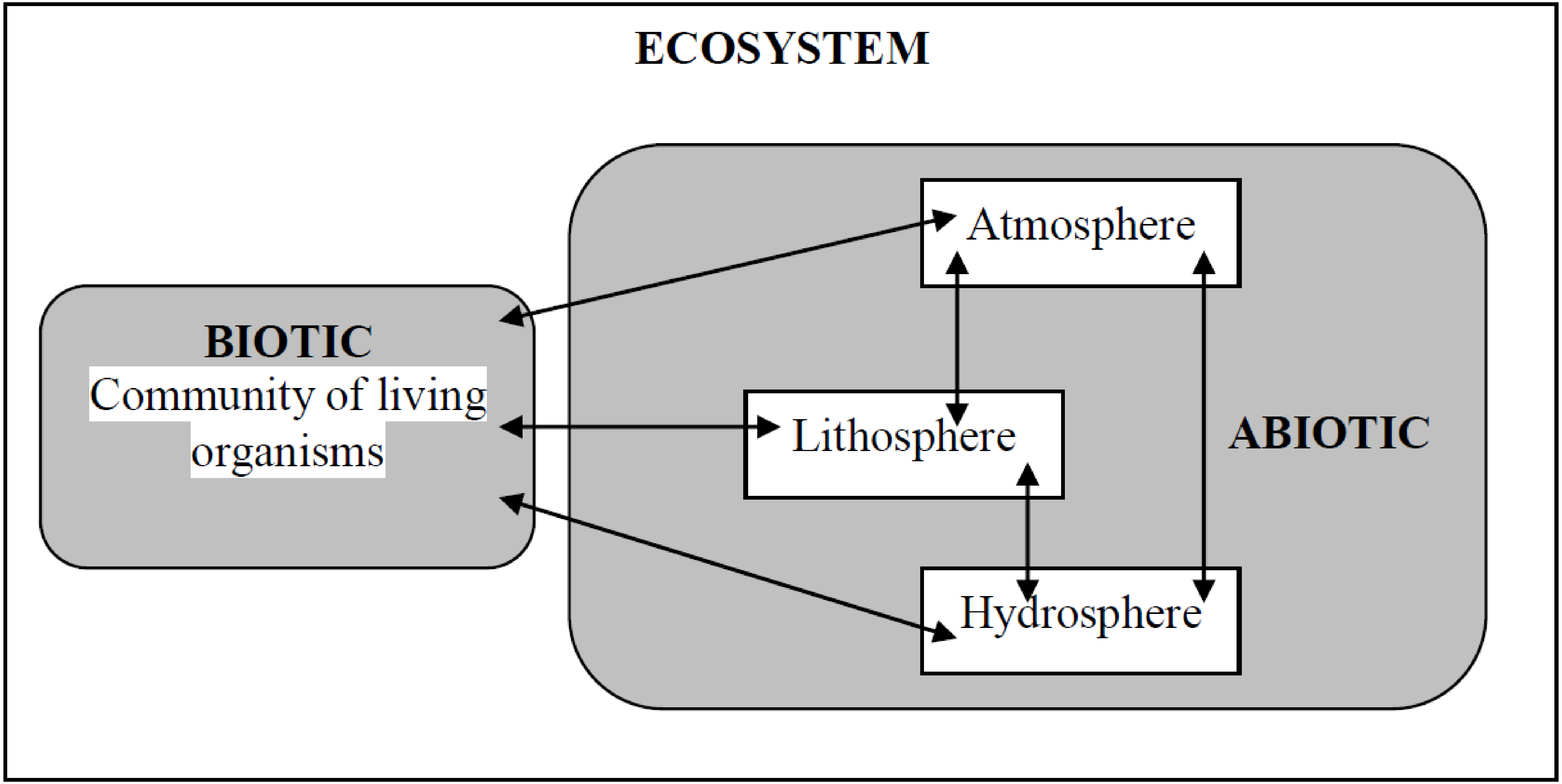
Ecosystem

- **Ecosystem** = 'ecological system'
- An ecosystem is a group of plants and animals, along with the physical environment with which it interacts.



Ecology examines the life histories, distribution and behavior of individual species, as well as the structure and functions of a natural system in terms of populations, communities, ecosystems and landscapes.

Environment: Based on structure



Structure of an ecosystem

- ***Biotic components (F,F,M.O)***
  - **Producers or Autotrophs**
    - autotrophic organisms -- manufacture their own food material
    - capture solar energy + simple inorganic substances (water, carbon dioxide, salts)
    - Food synthesized → growth, survival, and stored.

Structure of an ecosystem

- **Consumers or Heterotrophs**
  - heterotrophic organisms (nourished by others) consume the producers directly or indirectly.
    - ***Primary consumers/herbivores***: consume the producers directly
    - ***Secondary consumers/carnivores*** (flesh eaters): feed upon the primary consumers. Omnivores: feed on both flesh and plants
    - ***Secondary carnivores/tertiary consumers***: Carnivores which feed upon the secondary consumers, they are also called secondary carnivores,

Structure of an ecosystem

- **Decomposers/Micro-consumers/Reducers**
  - heterotrophic organisms which are saprotrophs
  - consume the food by absorption but not by ingestion.
  - mainly **fungi, bacteria and certain protozoans**
  - Decompose by

excreting enzymes + absorption

⬇

energy + inorganic nutrients, minerals and gases

(used again by autotrophs)

Structure of an ecosystem

- **Abiotic components**
  - non-living constituents of the environment i.e. the habitat.
  - *A habitat is a specific* ***set of physical and chemical conditions*** *that surrounds a single species, a group of species or a large community.*

Abiotic components

A. **Physical Factors**

- *Light* (sun as the main energy source),
- *temperature* (controls the climate)→Organism distribution,
- *evaporation and precipitation* (control climate), modulate
- *gravity* (controls rock material and hydrological cascade system, movement of matter, and orientation and distribution of animals),
- *pressure* (limits distribution of organisms),
- *humidity* (Transpiration and absorption of water)
- *air and water currents*. (weathering)

Structure of an ecosystem

b) **Chemical Factors**

- *Oxygen* → *Pulse of the environment*
- *Carbon dioxide* → *Raw material*
- *Minerals* (micro- and macro-nutrients)
- Organic matter (Carbohydrates, proteins and lipids)

Functional units of ecosystem

- Production and flow of energy
- Food web
- Food Chain
- Ecological pyramids
- Nutrient recycling
  - Biogeochemical cycles

Energy flow in the Ecosystem

- The sun is the primary source of energy

Primary producers → sunlight-using organisms

Photosynthesis → convert energy from sunlight into chemical energy

$6CO_2 + 6H_2O$ +2800 kJ energy from sun $\xrightarrow{\text{chlorophyll}}$ $C_6H_{12}O_6 + 6O_2$

Chemical Energy

Trophic Level

Type	Energy Source	Electron Donor	Carbon Source
Phototrophs	**Light**		
Chemotrophs	**Organic or inorganic compounds**		
Lithotrophs (chemotrophs)		**Reduced inorganic compounds (NH4)**	
Organotrophs (chemotrophs)		**Organic compounds**	
Autotrophs			**Inorganic compounds (e.g., CO_2)**
Heterotrophs			**Organic carbon**

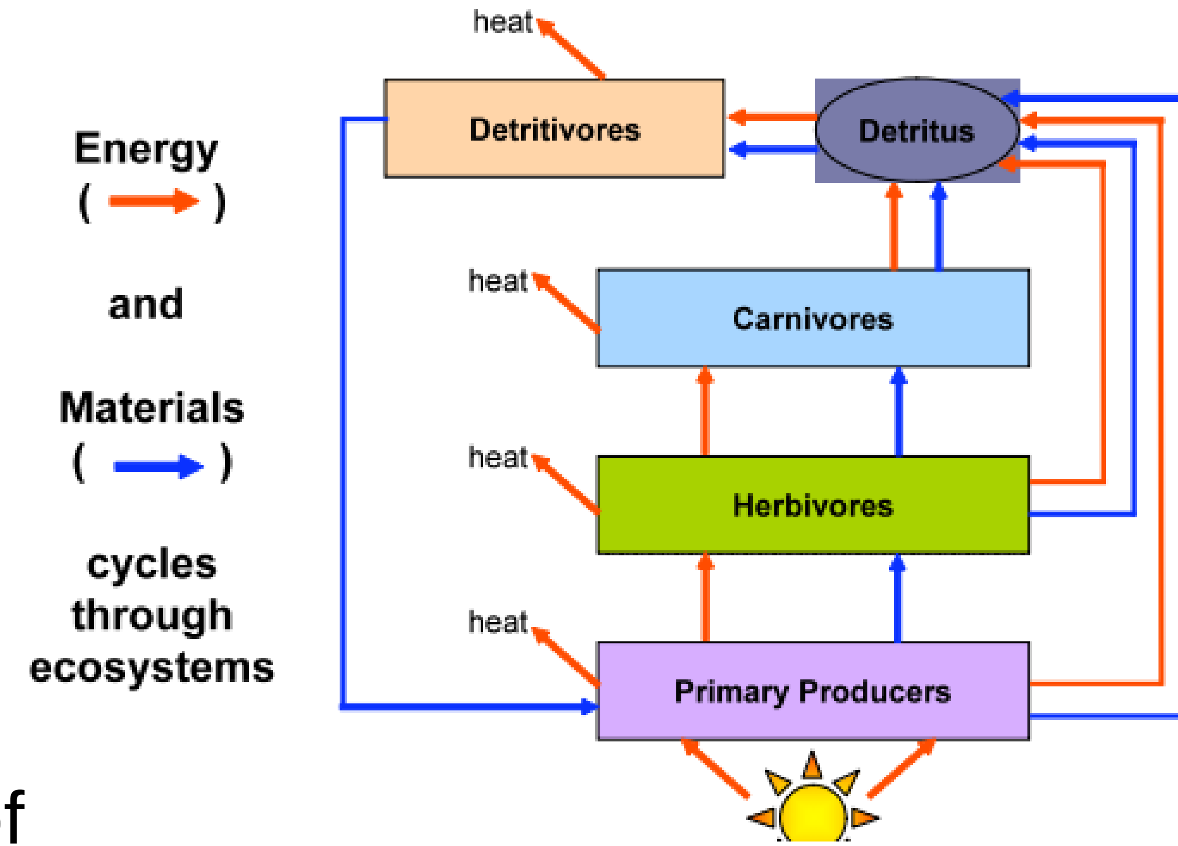
Energy flow in the Ecosystem

Gross primary productivity (GPP) The entire sun's energy that is assimilated by the photosynthetic activity of plants.

Net primary productivity (NPP).

energy remaining after respiration and stored as organic matter .

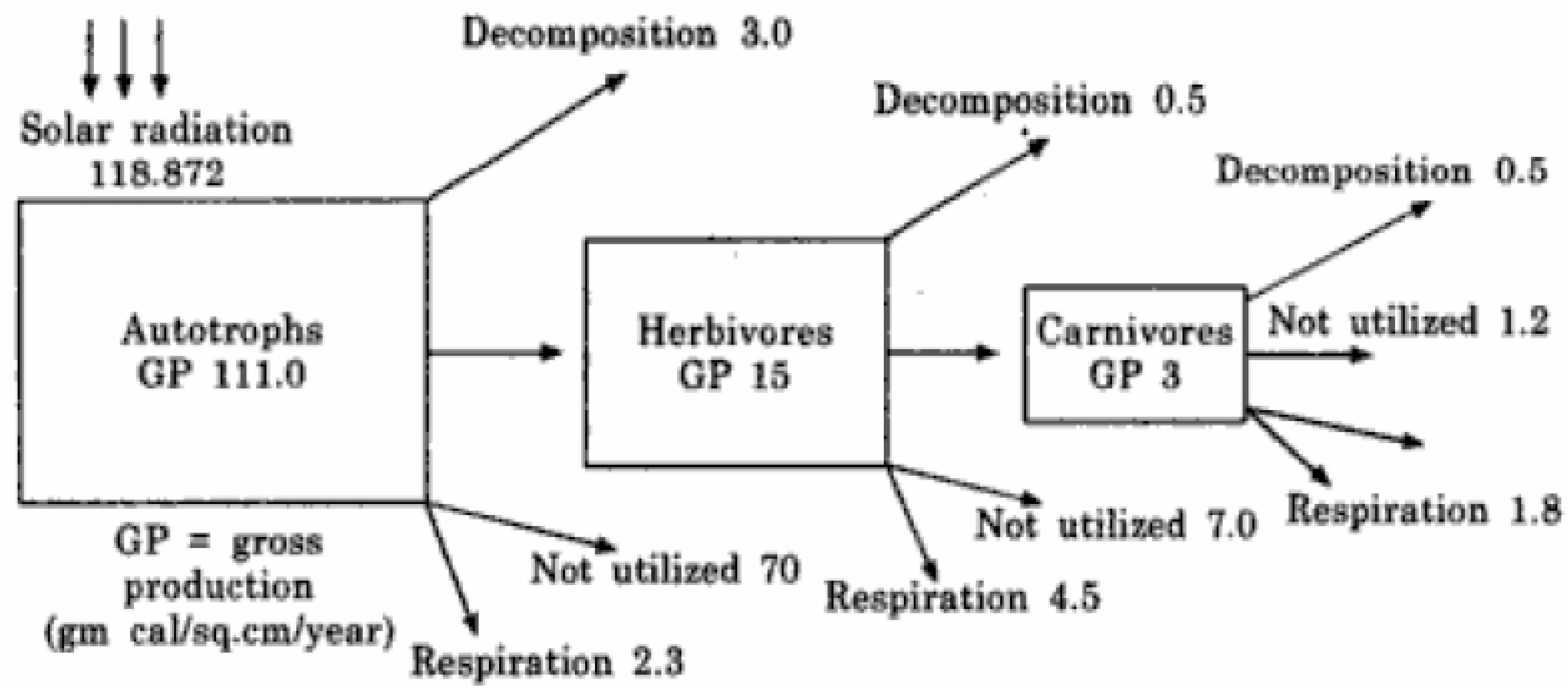
NPP=GPP-Respiration use of plant



Energy flow in the Ecosystem

- controlled by two laws of thermodynamics
  - Energy can neither be created nor destroyed.
  - Every transfer of energy is accompanied by its dispersion.
- depends on the following factors:
  - **Efficiency of producers** to trap solar energy and convert it into chemical energy
  - **Use of chemical energy** present in the producers by the consumers
  - **Amount of energy** present in the producers by the consumers
  - **Loss of energy** in the form of unused energy dead organism and heat during respiration.

Flow of Energy



Food Chain

"The transfer of energy and nutrients from one feeding group of organisms to another in a series."

- It is the sequence of eater being eaten, or who eats whom.
- Trophic level: successive level of nourishment
- In each transfer some energy is lost.
- → the shorter the food chain, or the nearer the organism to the beginning of the chain, the greater the energy available.

Food Chain

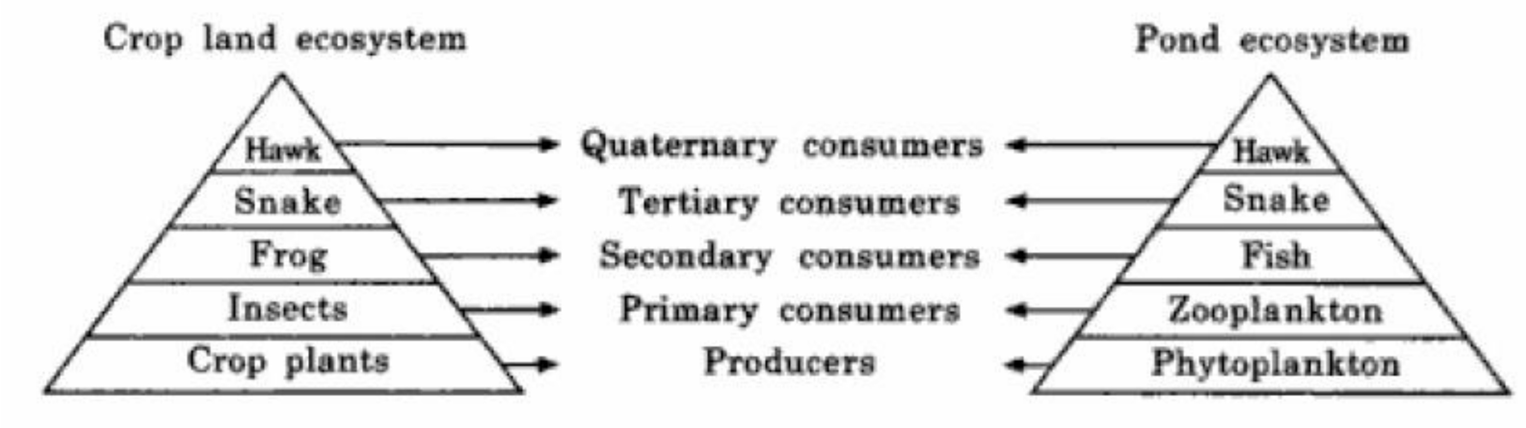
- Two major food chains
- *Grazing food chain*: Starts from living plants, goes through herbivores and ends in carnivores.
- *Detritus food chain*: Starts from dead organic matter and ends in inorganic compounds.

Food Webs

- **Food web**: Interconnected food chains
- Food webs maintain the stability of an ecosystem
- Complexity ← the diversity of species and their interconnectivity.
- Diversity of species← food habits
- Interconnectivity → alternatives
- Complex food webs are more stable than simple food webs.

Ecological Pyramids

- Ecological pyramids are the graphic representation of the number, biomass and energy of the successive trophic levels of an ecosystem.
- The loss of energy occurs
  - energy is not used efficiently
  - energy dissipates as kinetic energy and heat



Quiz

- From terrestrial & marine ecosystem, which one will most likely have higher number of trophic levels? Justify your answer.

Biogeochemical Cycles

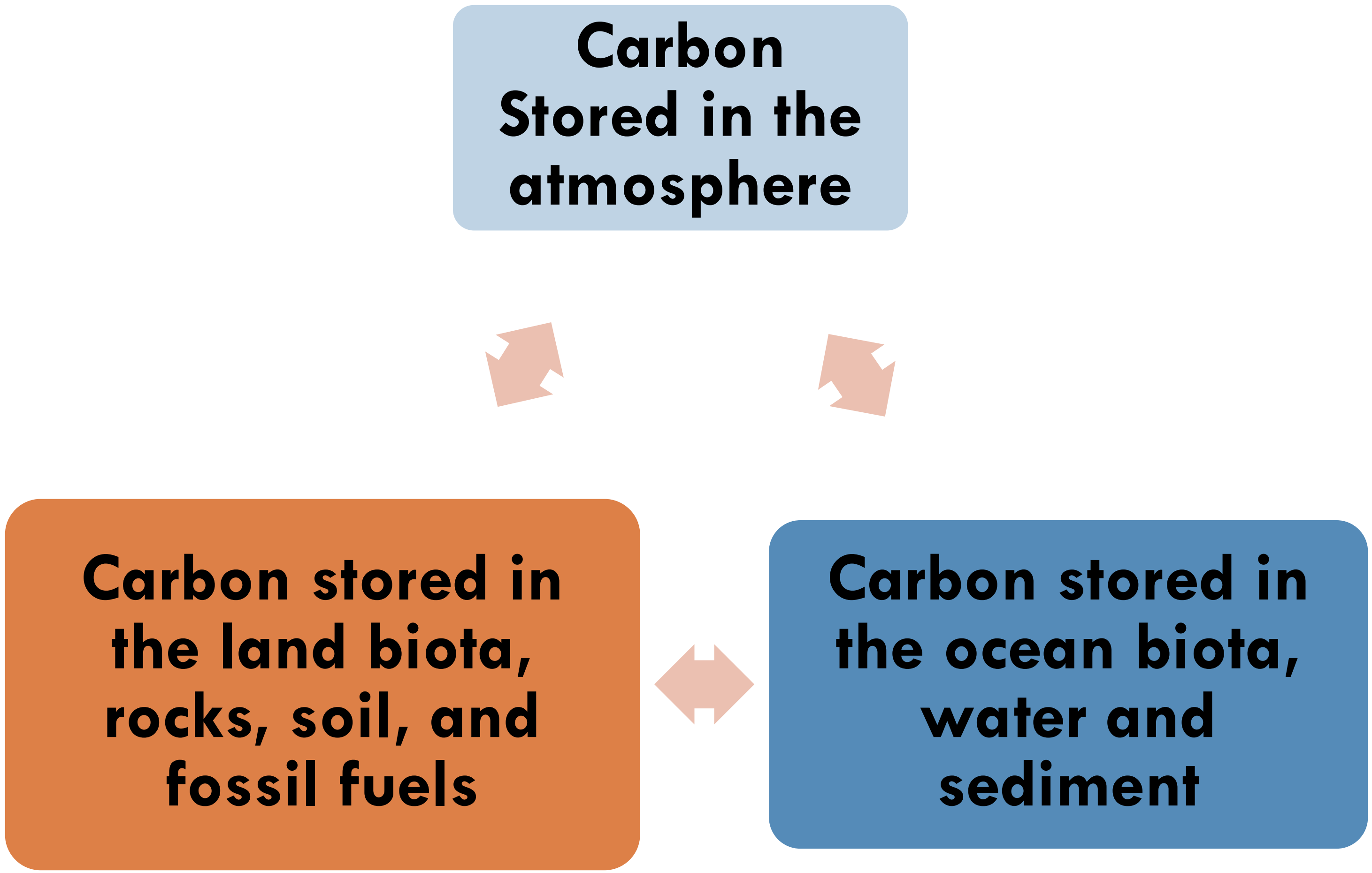
- **Biogeochemical cycle** is the complete pathway that a chemical element follows through the Earth system.

  - *bio-* because these are the cycles that involve life.
  - *geo*- because these cycles include atmosphere, water, rocks, and soils
  - *chemical cycle* because chemical elements are the form that we consider

Biogeochemical Cycles

- We are interested to know
  - The major chemical cycles
  - The importance of these cycles to life
  - The factors that control these cycles
  - The rate of these cycles
  - How each components of the Environment are involved
  - The impact of humans on these cycles

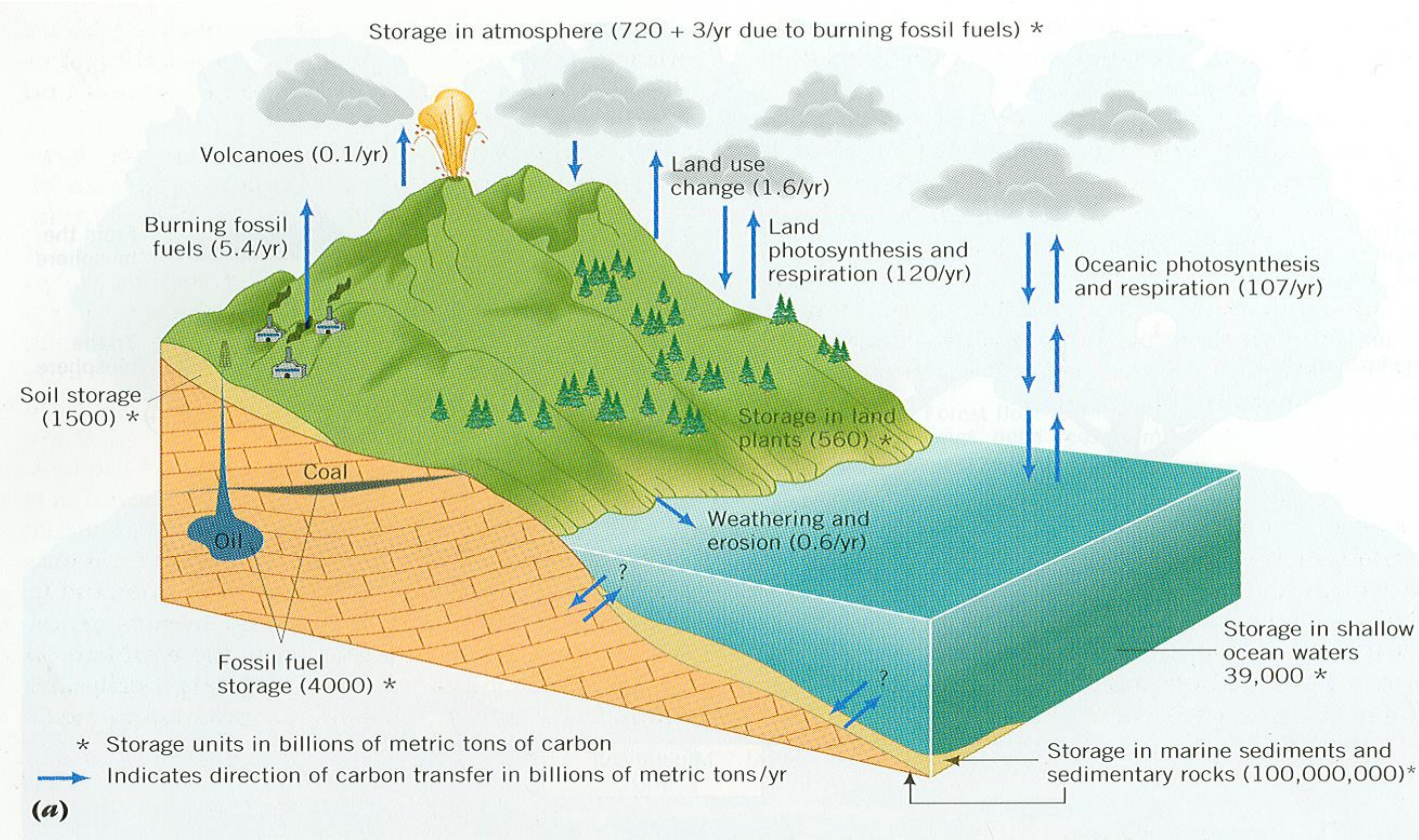
The Carbon Cycle



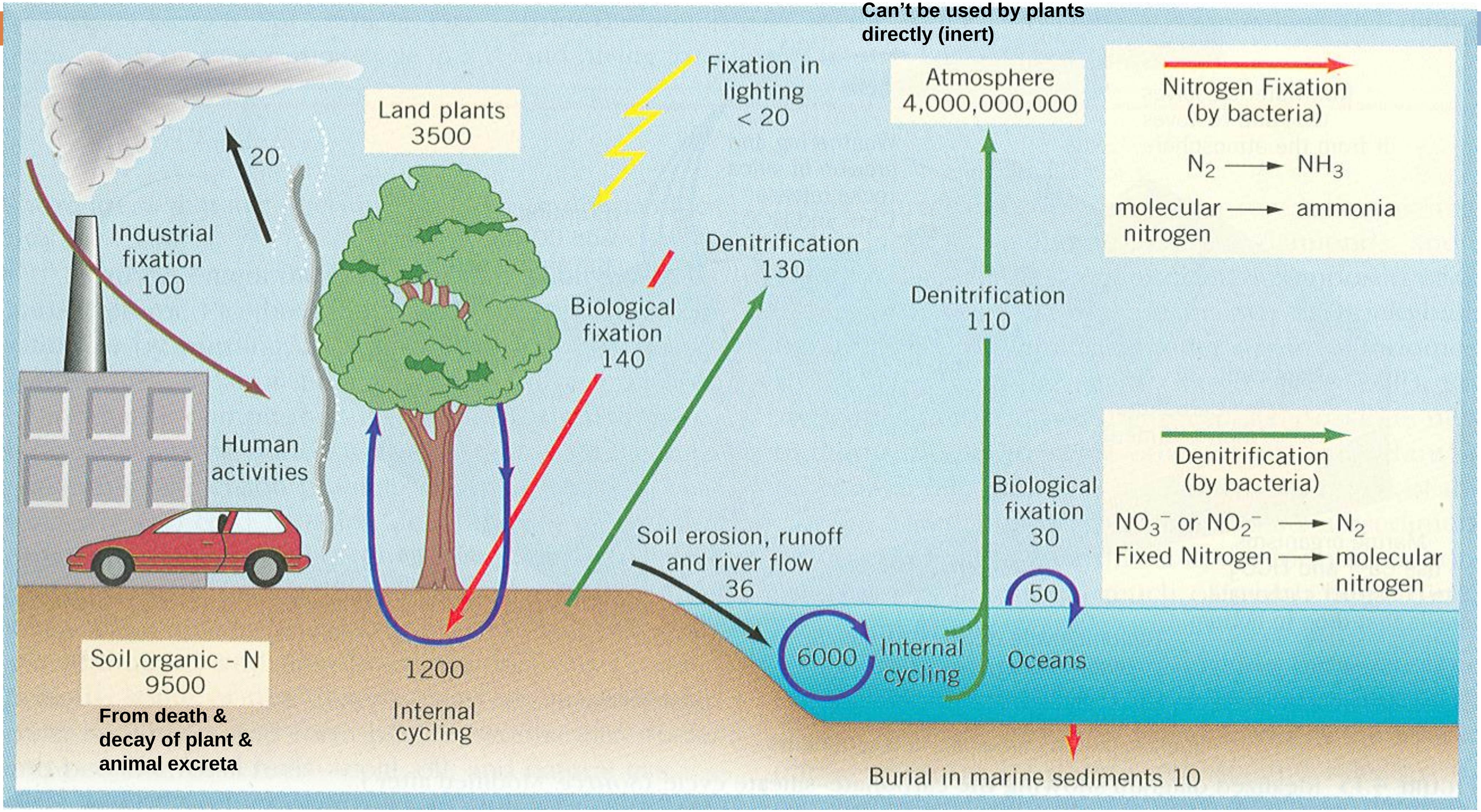
The Carbon Cycle

- Backbone of life
- CO_2 balance sheet per year
  - Fossil fuel burning 5.5 GtC / year
  - land-use changes 1.6 GtC / year
  - Totally due to human activities 7.1 GtC / year
  - 3.2 GtC remains in the atmosphere
  - 2 GtC diffuses in to the ocean
  - 1.9 GtC is unaccounted

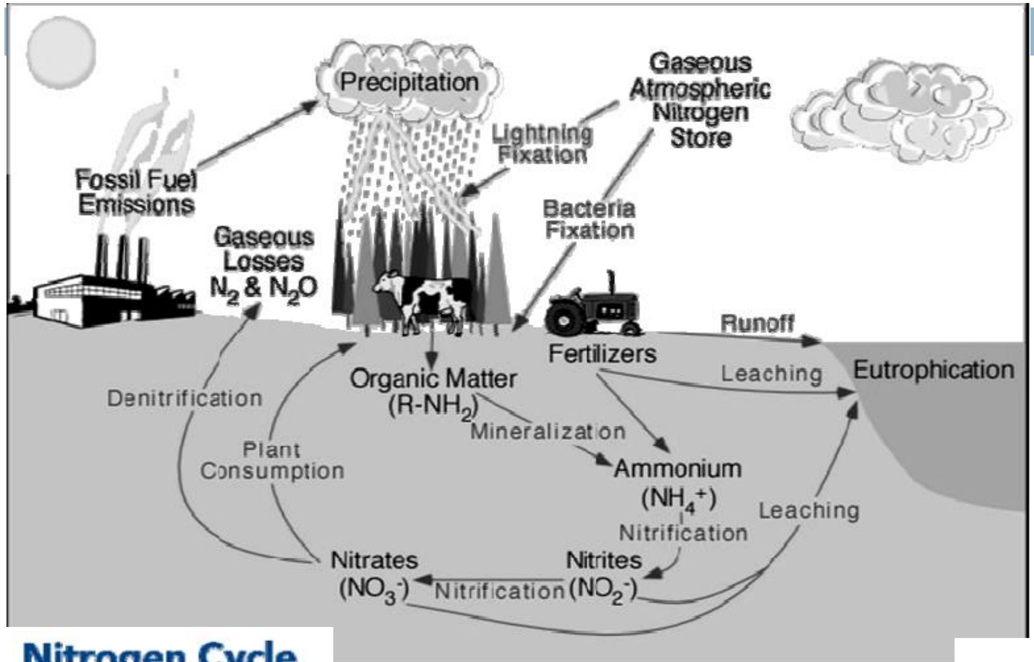
The Carbon Cycle



The nitrogen cycle



The nitrogen cycle



- Nitrification is a two step process by Nitrosomonas & Nirtobacter

Nitrification (aerated → aerobic conditions)

$2\ NH_4^+ + 3\ O_2 \rightarrow 2\ NO_2^- + 2\ H_2O + 4\ H^+$ (nitritation)

$2\ NO_2^- + O_2 \rightarrow 2\ NO_3^-$ (nitratation)

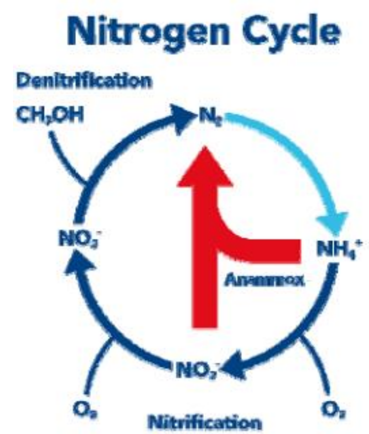
Autotrophic bacteria

Denitrification (not aerated → anoxic conditions)

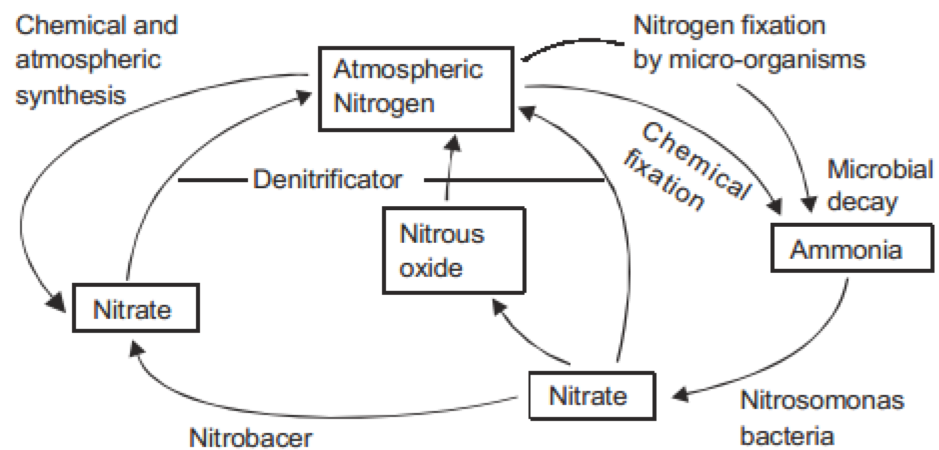
$5\ CH_3OH + 6\ NO_3^- \rightarrow 5\ CO_2 + 7\ H_2O + 3\ N_2 + 6\ OH^-$

Heterotrophic bacteria

- **Fossil fuel combustion**
- **Use of artificial nitrogen fertilizers**
- **Release of nitrogen in Wastewater**



Short cut in N-removal
Less Oxygen:- less Energy
No Organic Carbon:- more Biogas
BUT:
Need for preventing nitrite (NO2) oxidation
Very slow growing organism
(approx. 10 times slower)
:-Need for good biomass retention



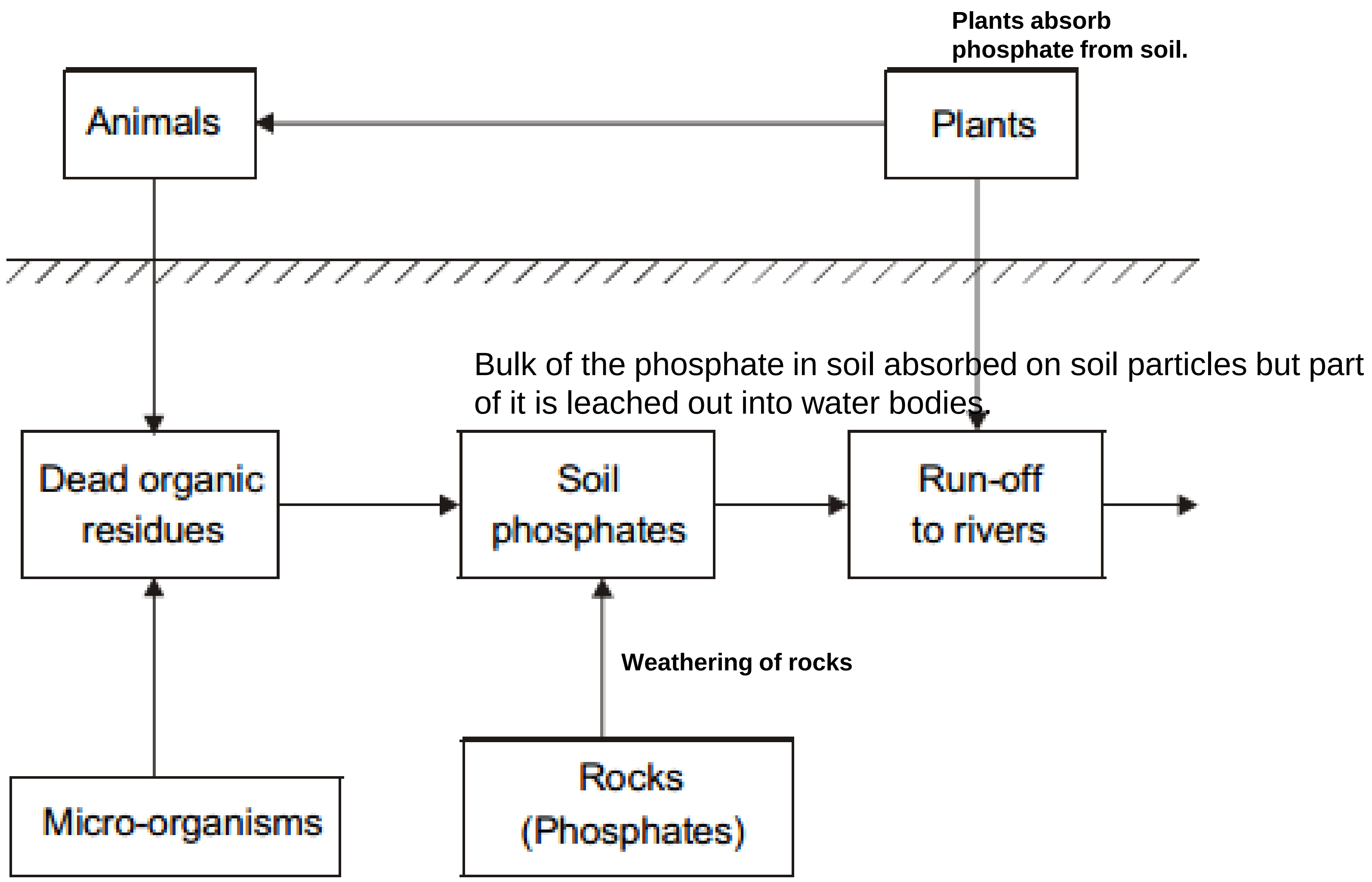
Anammox: $NO_2^- + NH_3 + H^+ \rightarrow N_2 + 2\ H_2O$

The phosphate cycle

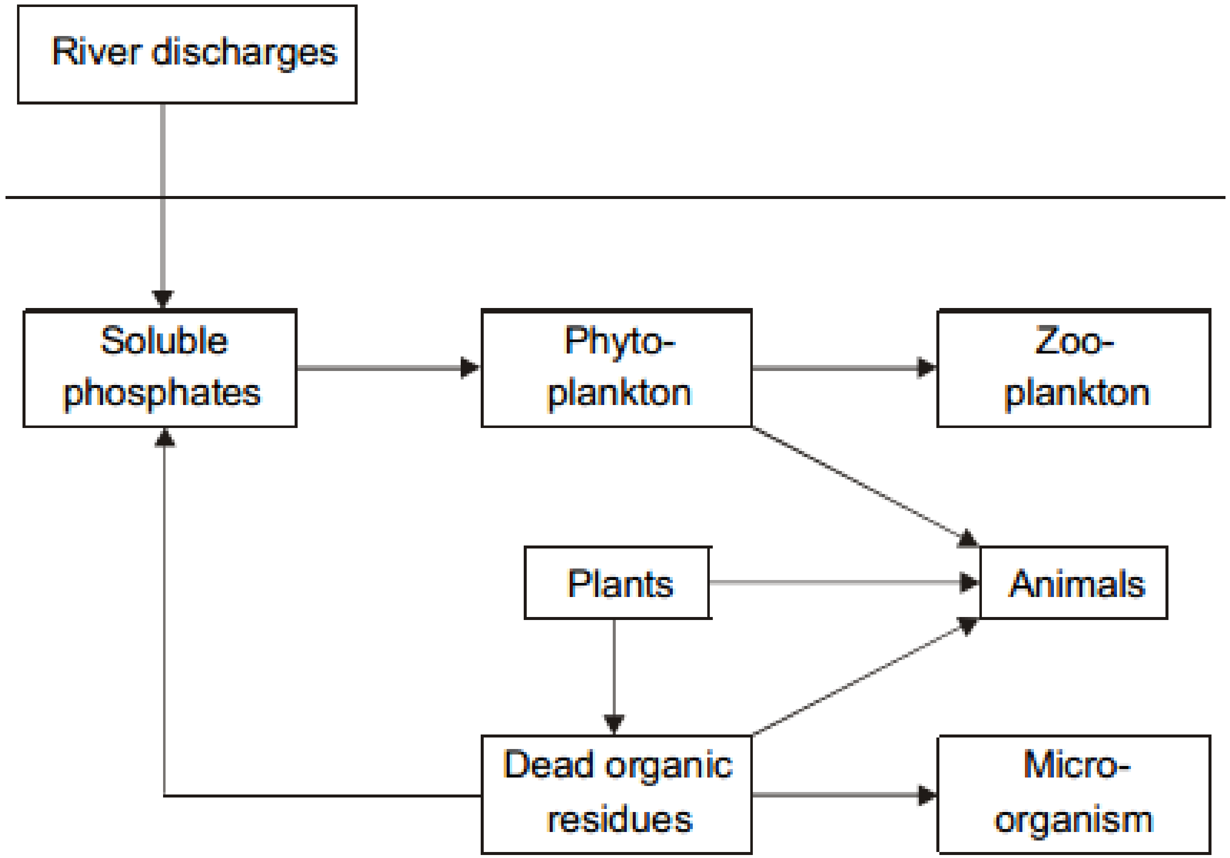
- Phosphates (PO_4) → bones and teeth
- Organo-phosphates → cell division (DNA & RNA)
- The phosphate cycle doesn't include gas phase (atmosphere role is less)
- The slowest process of biogeochemical cycles.
- Phosphate is a limiting nutrient of aquatic life
- Affected by Excess use phosphate fertilizer→ *eutrophication*

  Domestic sewage

The phosphate cycle



The phosphate cycle

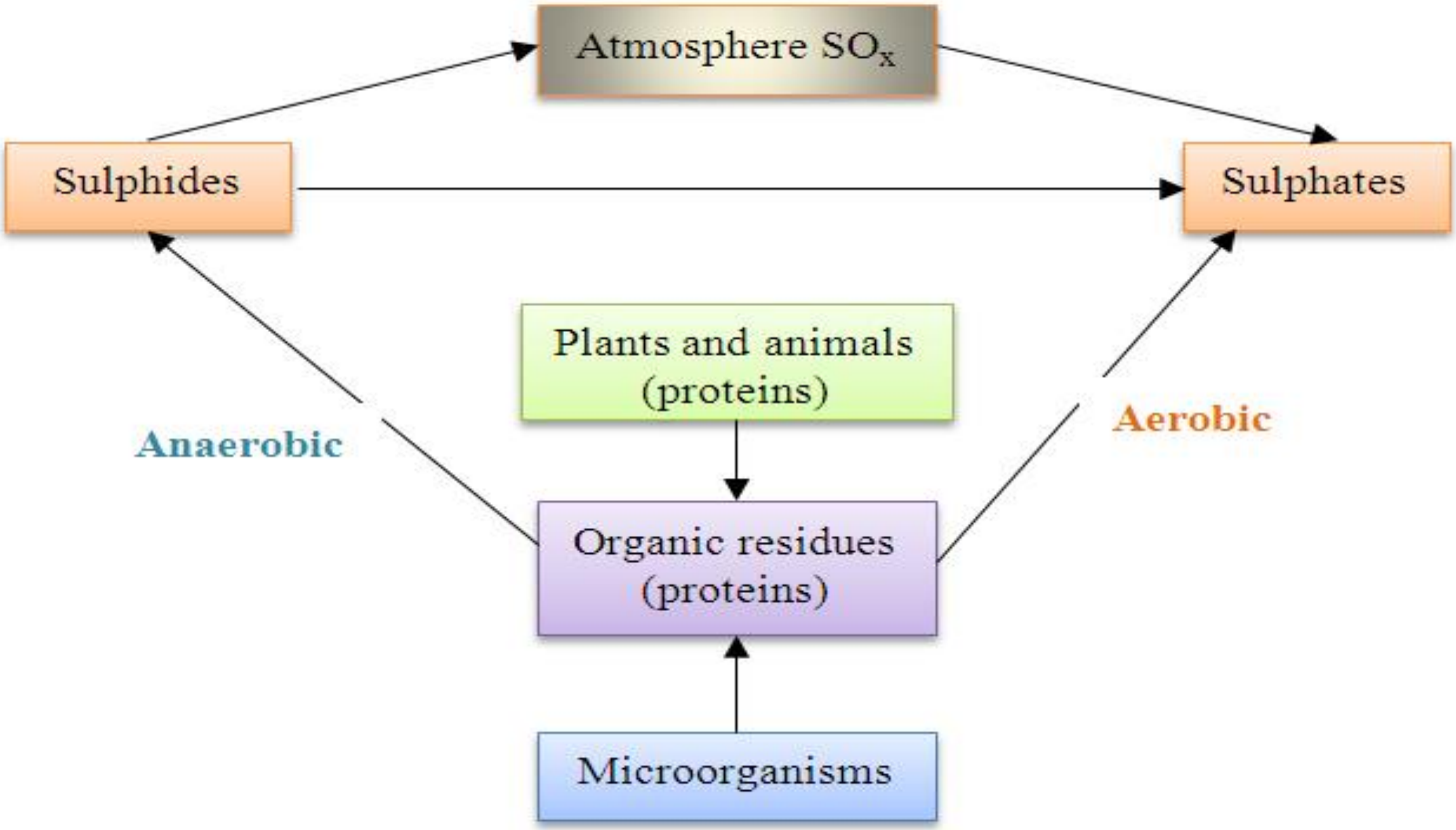


The phosphate cycle in water

The Sulfur Cycle

- Sulfur (S), the tenth most abundant element in the universe
- Sulfur (compounds) →to synthesis certain amino acids and proteins
- Humans impact by burning of fossil fuels and the processing of metals.
- 90% of sulfur dioxide due to human activities.
- Ultimately→ sulfate salts → acid rain/offset global warming

The Sulfur Cycle



Impacts on the Environment

- The Earth has limited resources to support populations of humans and other organisms.
- Ever increasing human numbers is depleting many of our planet's resources and placing severe stress on the natural processes that renew many of our resources.

Ecosystem Processes

Ecosystem Process	Human Influence
Generation of Soils	Agricultural practices have exposed soil to the weather resulting in great loss of topsoil.
Control of the Water Cycle	The cutting of forests and other human activities have allowed increased uncontrolled runoff leading to increased erosion and flooding.
Removal of Wastes	Untreated sewage wastes and runoff from farms and feedlots have led to increased water pollution.
Energy Flow	Some industries and nuclear plants have added thermal pollution to the environment. The release of some gases from the burning of fossil fuels may be slowly increasing the Earth's temperature. (Greenhouse Effect).
Nutrient Recycling	The use of packaging material which does not break down, burning of refuse, and the placing of materials in landfills prevents the return of some useful materials to the environment.

Some Detrimental Human Activities

Human Influence	Effect on Ecosystems
Population growth	We are using excessive amounts of the Earth's limited resources.
Overconsumption	Industrialized societies are using more resources per person from our planet than people from poor nations.
Advancing Technologies	Often we introduce technology without knowing how it will influence the environment
Direct Harvesting	resulted in a large loss of rainforest and its biodiversity.
Pollution	have had many adverse influences on ecosystems.
Atmospheric Changes	Greenhouse gases mostly due to the burning of fossil fuels and depletion of our stratospheric ozone layer and negative effects on living things.

Positive Influences of Humans on the Ecosystem

- Sustaining endangered species → habitat protection methods (wildlife refuges and national parks.)
- Passing wildlife management laws →game laws and catch restrictions.
- Design new products →without generating pollution.
- Inspection of all materials before entering a country to prevent pest introduction.
- Increased use of **biodegradable** packaging materials which will recycle themselves quickly to the environment.
- Use fuels which contain less pollutants, such as low sulfur coal and oil.
- Remove pollutants by using such devices as afterburners or catalytic converters before they enter the air.

Major Global Environmental Hazards

- Population growth
- Urbanization
- Industrialization
- Loss of biodiversity
- Global warming
- Inversion
- Acid rain
- Ozone depletion in the stratosphere

Population growth and standard of living

- 2 million years for the world population to become 1 billion
- l00 years for 2 billion (1930),
- 30 years for 3 billion (1960),
- 25years for 4 billion (1985) and
- 12 years for 5 billion (1997).
- impact of human← standard of living (needs and desires) and the efficiency with which these needs can be met.
- The *ideal per capita resource usage* is the minimum amount of resources and environmental degradation required to achieve that standard of living.
- The minimum ideal per capita resource usage: the actual per capita usage multiplied by an *environmental efficiency*.

Population growth and standard of living

$$\text{Environmental Impact} \propto \frac{(\text{Population}) \times (\text{Ideal Per Capital Resource Usage})}{(\text{Environmental Efficiency})}$$

Population growth and standard of living

$$\text{Environmental Impact } \alpha \ \frac{\text{(Population) x (Ideal Per Capital Resource Usage)}}{\text{(Environmental Efficiency)}}$$

- Three factors of population, ideal resource usage, and environmental efficiency are not independent.
- Environmental engineers focus is on environmental efficiency → minimizing the environmental impact per unit resource usage or standard of living.

Impact of Population

$$I = P \times A \times T$$

- **I** is environmental impact,
- **P** is population (including size, growth, and distribution),
- **A** is the level of affluence (consumption per capita), and
- **T** is the level of technology.

Average per-capita consumption of energy

- In a hunting society →20 MJ/d
- In a primitive agricultural society → 48 MJ/d,
- In advanced agriculture →104 MJ/d,
- In industrializing society →308 MJ/d, and
- In an advanced industrial society→1025 MJ/d.

Rich Vs. Poor

	Industrialized	Less-developed
Population	25%	75 %
Average Citizen Energy (GJ/yr)	199	17
Total Energy Utilized	80%	20%

- the world's richest 20% of people consume 86% of the goods and services delivered by the global economy, while the poorest 20% consumes just 1.3%
- the United States—consumes approximately 25% of the world's natural resources and produces 75% of its **hazardous wastes** and 22% of its greenhouse gas emissions, while having only about 4.5% of the world's population

Urbanization

- The physical growth of urban areas as a result of rural migration
- Employment opportunities, educational, Medicare, and infrastructural facilities

Urbanization

- Agricultural land can decrease
- heavy demand for housing, water supply systems, waste treatment & disposal facilities, transportation, and other public facilities like: commerce, hospitals, hotels, educational facilities

Urbanization: Effects

- more vehicles →traffic congestion and pollution
- Solid wastes → unhygienic and unsanitary conditions
- less open space → temperature increase and disappearance of surface water bodies
- Quality of life → more strenuous

Urbanization: Remedies

- Implement effective methods of reducing the migration trends to urban areas
- Developing satellite townships
- Zoning city's master plan
- Provide basic facilities for slum areas
- Provide alternate energy sources
- **Focus on** pollution control

Industrialization

- A **Goal** pursued by all nations → standard of living →more demand → resource depletion → more environmental degradation
- **driven by** energy consumption from **coal, petroleum**, and **natural gas**.
- **GNP (Gross National Product):** the sum of all personal and governmental expenditures on goods and services within a country, including the value of net exports.
- **GEI (Gross environmental improvement):** a component of the GNP that includes the cost of environmental improvements. (such as money spent on reforestation or pollution control measures)

Industrialization

<u>Major attributes of natural ecosystems</u>:

1. Waste minimization and materials recycling

2. Optimization of energy consumption

3. Diversity of components and redundancies of both organisms and links between them

4. Nonlinear dynamics (i.e. lack of proportionality between cause and effect)

5. Decentralized control.

<u>Contrasting attributes of our current industrial systems</u>:

1. Most material flows are linear (do not form closed loops); we create excessive waste.

2. Liberal use of energy; also our energy is most often at high temperatures

3. Diversity of products and companies; competition

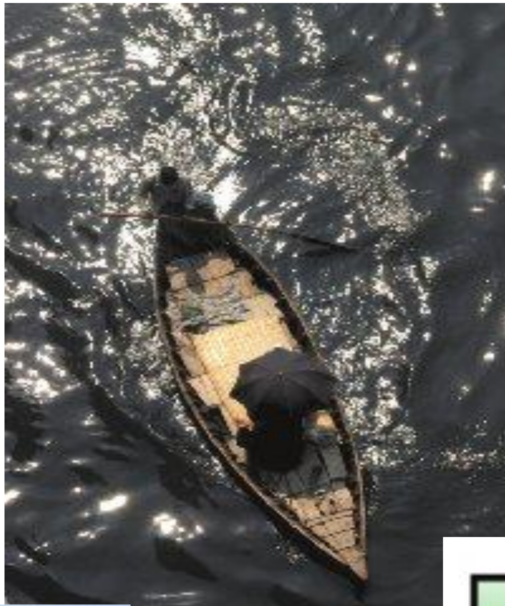
4. Nonlinear market economics

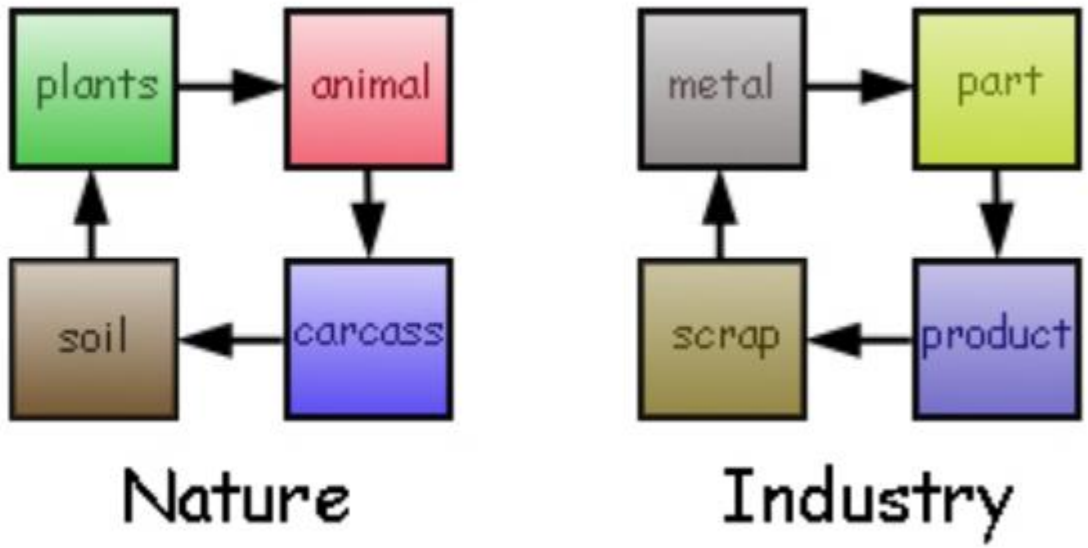
5. Industrial systems are relatively decentralized except for a certain degree of command-and-control regulations on the part of the government.

In conclusion, we are doing ok with respect to items (3), (4) and (5), but we are very much unlike nature when it comes to items (1) and (2).

Industrialization : Wastes

- Liquid wastes,
- gaseous, solid wastes
- nuclear waste.

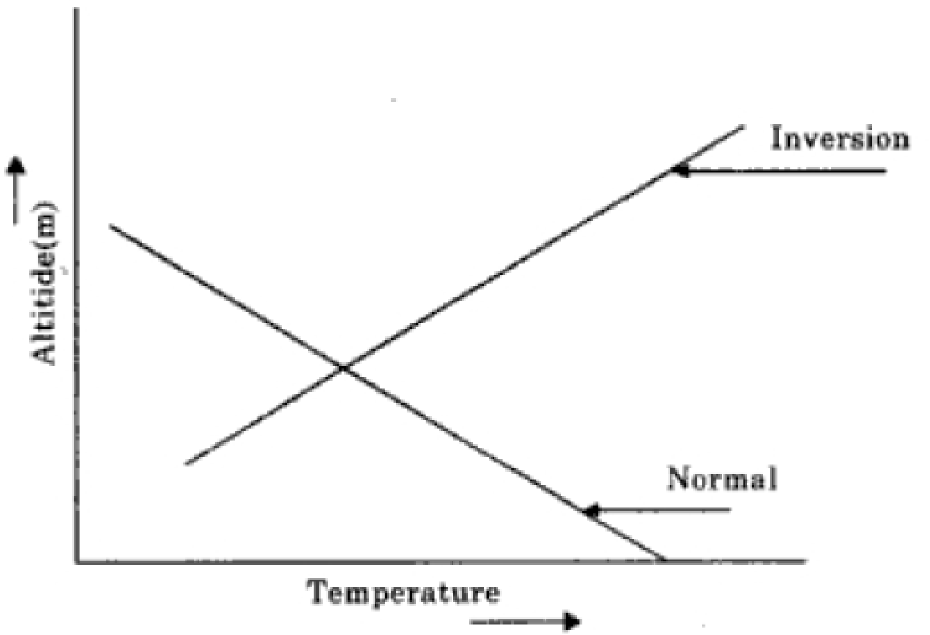




Inversion

- Atmospheric temperature normally decreases with altitude.
- Morning fog, valleys, low lying areas & coastal areas
- If a parcel of air is warm, it moves up until its own density equals with its surroundings. → air circulation → dispersion of pollutants
- If no movement of air→ pollutant accumulation the ground level

Inversion



- gaseous pollutants are minimized at source;
- the stack height is adequately increased; and
- care is taken at the time of locating the industries

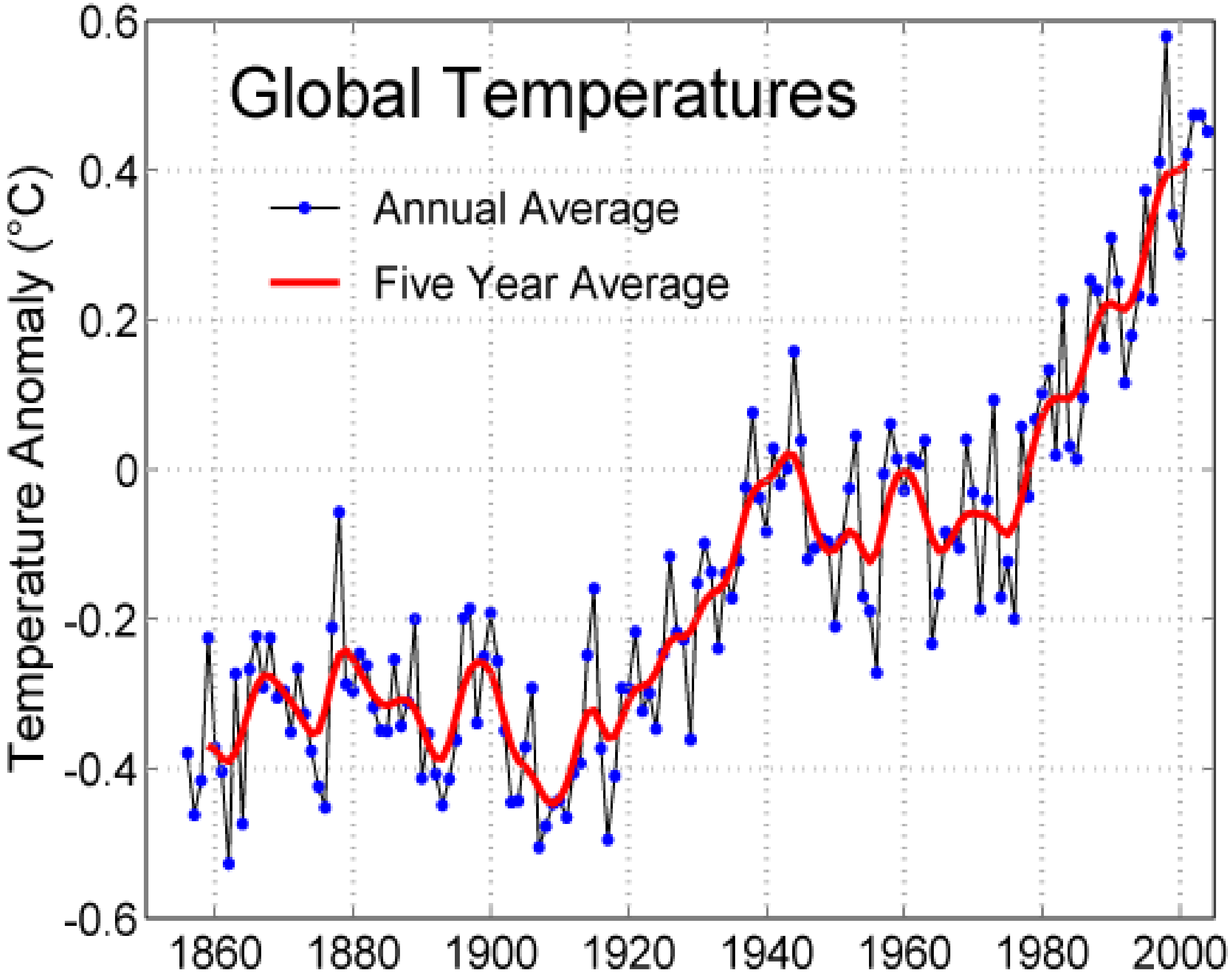
Acid Rain

- $H_2O + CO_2 \rightarrow H_2CO_3$
- $2SO_2 + H_2O + O_2 \rightarrow 2H_2SO_4$
- $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$

•damage building & structure
•reduces soil fertility & crop yield
•affects aquatic organisms
•irritation to skin and respiratory tract
•toxic chemicals
•Corrodes ancient monuments

Global Warming

Carbon dioxide and other gases warm the surface of the planet naturally by trapping solar heat in the atmosphere.

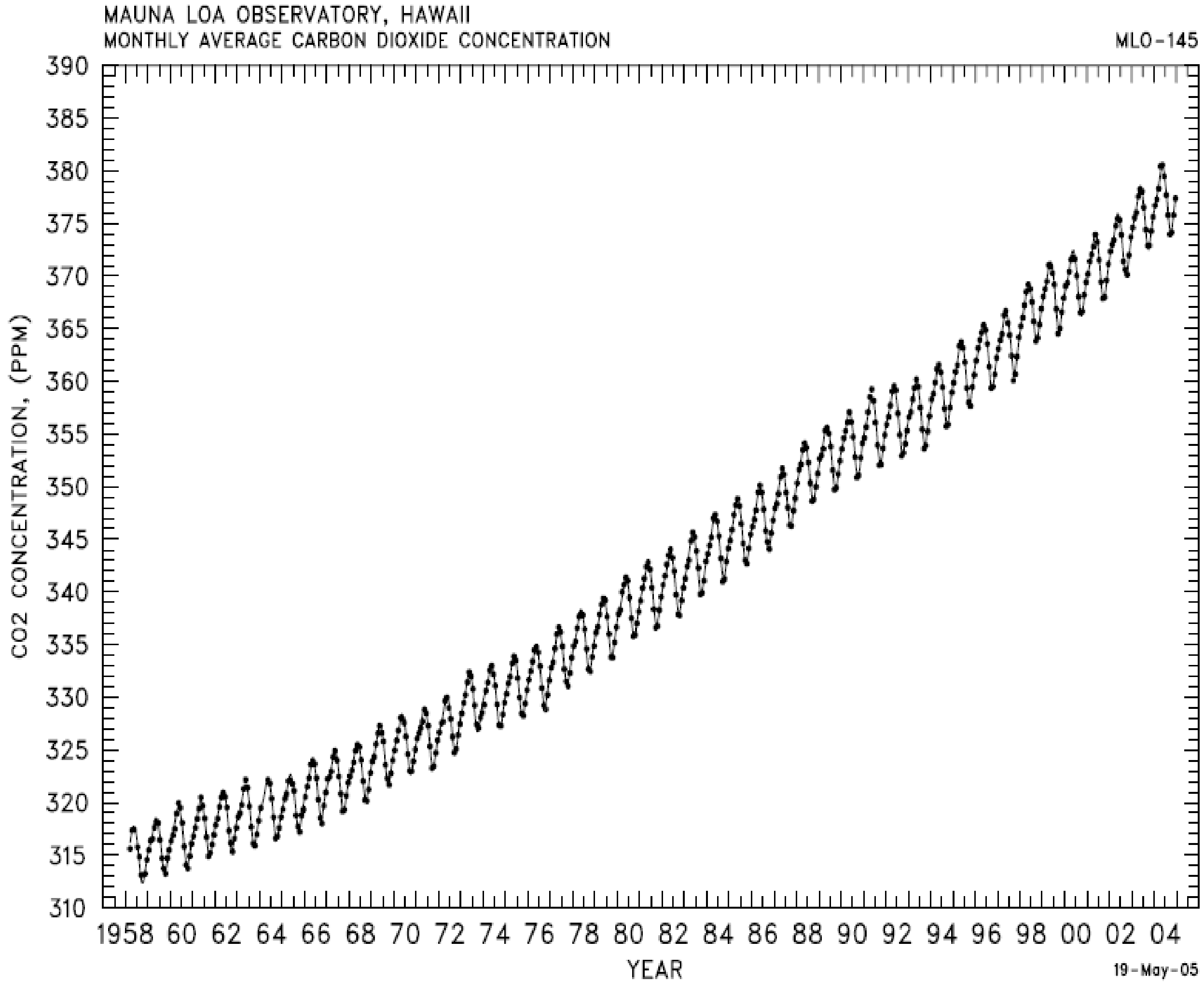


Global Warming

Rapid increase in atmospheric carbon dioxide

Carbon dioxide levels fluctuated between 180 - 300 ppm over the past 150,000 years.

But it change from 280 ppm → 360 ppm (370 ppm) since1950,



Global Warming

Adverse effects

- Rise in sea level to 3.5 - 34.6 in. (9-88cm) → Erosion, Flooding and Permanent inundation
- Severe stress on many forests, wetlands, alpine regions, and other natural ecosystems
- Greater threats to human health as insects and rodents spread diseases
- Disruption of agriculture due to increased temperature, water stress and sea-level rise in low-lying areas such as Bangladesh or the Mississippi River delta.
- Heat waves will be more frequent and more intense.
- Droughts and wildfires will occur more often.
- The Arctic Ocean could be ice free in summer by 2050.
- More than a million species worldwide could be driven to extinction by 2050.

Loss of biological diversity

Biodiversity refers to the wide variations seen in plant and animal life on the planet. At least three types of diversity exist.

- *Genetic diversity* - Variation between individuals of the same species
- *Species diversity* - Variation within an ecosystem by the presence of different species
- *Ecosystem diversity* - Variations within and among species in different ecological environments

Loss of biological diversity

Reasons to protect biological diversity.

- **Moral, ethical, aesthetic ,to protect and preserve** the beauty of the natural environment
- **Gene-pool preservation** - A broad gene-pool provides a source of plant and animal traits that may be introduced into valuable agricultural products
- **Gene-pool diversity** - Biodiversity preserves traits that may be needed **to adapt to a changing environment** or conditions
- **Important products** - Many important medicines are extracted from natural plants and , in addition, many plants have never been evaluated for commercial or medical benefits; retention of biodiversity ensures that these products will be available when found
- **Ecosystem stability** - Ecosystems depend on a variety of interdependent organisms to survive and thrive, and elimination of any one organism could threaten the survival of the entire ecosystem.

Loss of biological diversity

Devastation causes the following:

- Human, animal and plant life or the entire ecosystem is lost.
- Buildings and infrastructural facilities are severely damaged
- Road, railway and other communication systems collapse completely.
- Water supply and power systems fail.
- Crops and cattle feed get spoilt beyond use.
- Cholera, plague and other epidemics spread.
- Economic and social disturbance increases