ECOSYSTEMS

Syllabus

- Definition
- Scope and Importance of ecosystem.
- Classification, structure and function of an ecosystem
- Food chains, food webs and ecological pyramids.
- Flow of energy
- Biogeochemical cycles
- Bioaccumulation
- Biomagnifications
- Ecosystem value, services and carrying capacity.

INTRODUCTION

Environment is the physical and biotic habitant (living place of organisms) which surrounds us; that which we can see, hear, touch, smell and taste.

Environment = **Physical Environment** (Non-living system which includes water, land, air) + **biological environment** (which includes plants, animals and microorganisms)

CONCEPT OF ECOSYSTEM

Eco:- Region of space where living things can exist

System:- Interacting organism in a particular habitat (living place)

Definition of Ecosystem

- System resulting from the integration of all the living and non-living factors of the environment.
- Plants, animals and other organisms together with the physical environment with which they interact constitute ecosystem

SCOPE AND IMPORTANCE OF ECOSYSTEM

- Ecosystems are communities of organisms and non-living matter that interact together.
- Each part of the ecosystem is important because ecosystems are interdependent.
- Damaged or imbalanced ecosystems can cause many problems.

Classification of ecosystem

Ecosystem can be classified based on size, nature and duration

On the basis of nature

1.Natural: This ecosystem forms naturally without interference of human. Example: pond, river, forest, village, hill etc.

2. Artificial Ecosystem: This ecosystem is developed and maintained by human. Example: flowerbed, backyard, aquarium etc.

On the basis of duration

1. Temporary ecosystem: it is short lived and man made or natural. Example include rain fed pond.
2. Permanent ecosystem: it is long lived and self supported natural ecosystem for very long period. Eg: forest, river..

On the basis of size

1. Small: it is small and also known as microecosystem. It can be temporary or permanent. Ex. Pond, flowerpot etc
2. Large: it is large in size and also known as macroecosystem. It is always permanent and mostly natural. For ex. Ocean, river, forest and desert.

COMPONENTS OF ECOSYSTEM

- **Abiotic component:-** Physical environment which consists of light, heat, wind etc. and it provides environment and raw materials for the synthesis of organic food.
- **Biotic environment:-** the living autotrophic bacteria and green plants (**producers)** are capable of trapping solar radiations to form organic matter by combining CO_2, H_2O and minerals. These organism provide food directly or indirectly to all heterotrophic organisms (**consumers)**

STRUCTURE OF ECOSYSTEM

- **Structure**:- description of the composition of biotic and abiotic components in a particular habitat.
- **Abiotic component:-** The term abiotic means without life.

Chemical abiotic component: Inorganic (C, CO_2, H_2O etc.) and Organic (Fats, proteins etc.)

Physical abiotic component: Edaphic (relate to soil and act as a solid medium for variety of organisms like bacteria etc.), Climatic (Wind, water, temperature, light and rain),

Topography (Surface behaviour of earth like slope, altitude. Hills etc.). Abiotic components are the physical environment which consists of light, heat, wind etc. and it provides environment and raw materials for the synthesis of organic food.

- **Biotic environment:-** The living organisms (plants, animals, microorganisms) constitute biotic components of the ecosystem. From nutritional point of view biotic environment are classified as:-

Autotrophic and heterotrophic components

➢ *Autotrophs or Producers:* Producers are the base for biotic community in an ecosystem. They are capable of trapping solar radiations to form organic matter by combining CO_2, H_2O and minerals. They are also termed as autotrophs as they are capable of synthesizing their own food. They are capable to change radiant energy into chemical energy so they are also known as transducers. These are two types- phototrophs and chemotrophs

Phototrophs:- those which produce their food through

photosynthesis, eg: green plants,

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Chemotrophs:- those which produce food through chemosynthesis (exothermic oxidation of inorganic or simple organic molecules without aid of light).

$$CO_2 + 4H_2S + O_2 \longrightarrow CH_2O + 4S + 3H_2O$$

Heterotrophs or Consumers: organisms which depends on autotrophs or primary producers. These are called consumers because they consume the matter built up by the producers. Producers provide food directly or

depending upon their food habits, they are classified as

(a) Primary consumers or herbivores: Obtain food directly from plants Eg: Cow, goat etc

(b) Secondary consumers**:-**these are carnivores and eat flesh. Eg: Lion, birds etc.

(c) Tertiary consumers**:-**these are the top carnivores feed both on primary and secondary consumers. Eg: Lion, tiger etc.

Omnivores: These are herbivores as well as carnivores are those which eat both flesh and plant**. Eg:- Man, dogs etc.**

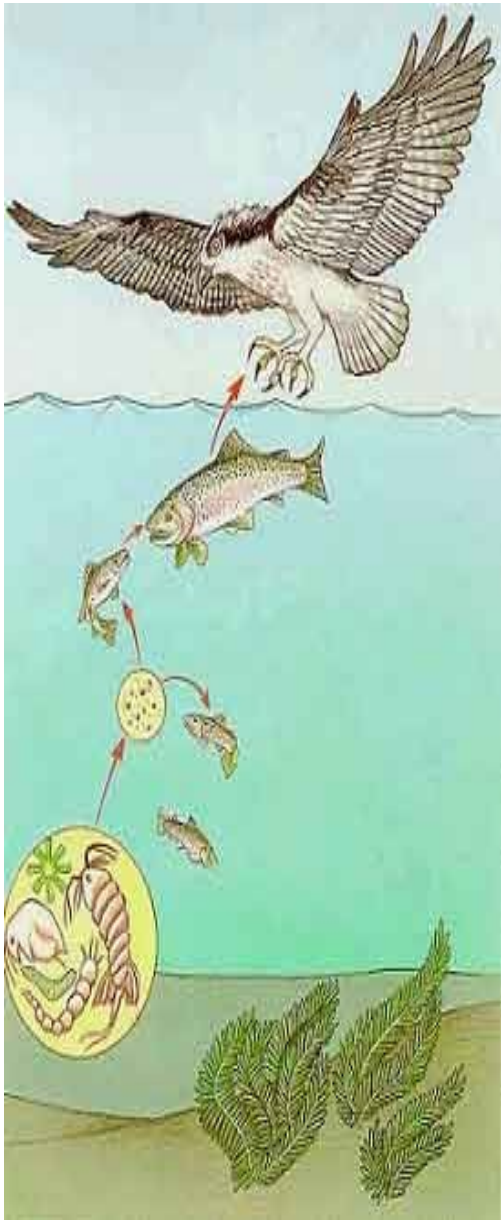
Decomposers: those organisms which eat dead organic matter. Eg:- bacteria, fungi etc.

FUNCTION OF ECOSYSTEM

- Nutrient cycles – biogeochemical cycles
- Energy cycle
- Diversity/Interrelation – inter linkages between organisms
- Cybernetics
- Food chain and food web

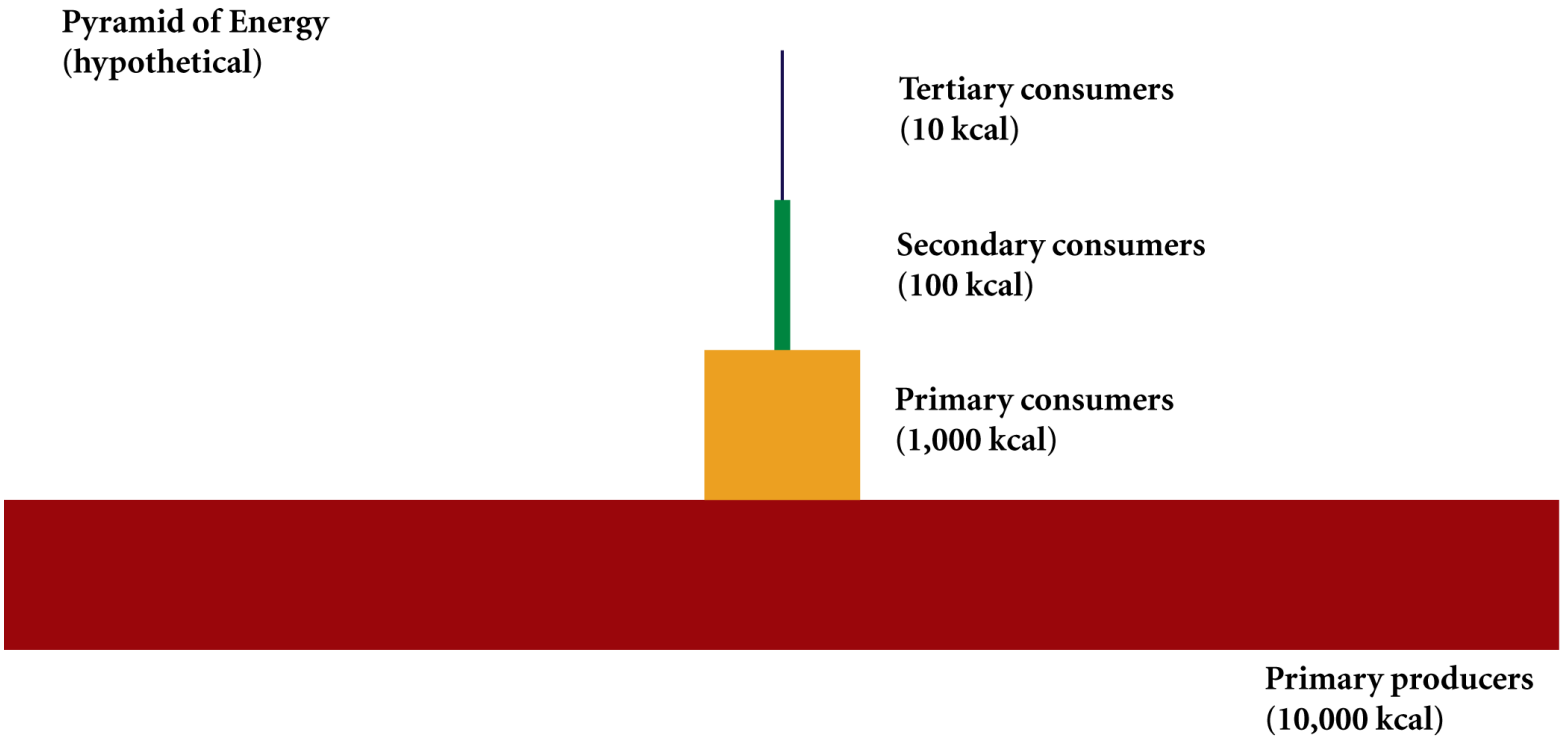
Nutrientcycling:-

Autotrophic plants obtain a number of inorganic nutrients from the environment, which become components of organic matter. From producers it goes into consumers and then through decomposers it goes into environment. Thus nutrient is circulating between living and non-living organisms by different biogeochemical cycles.

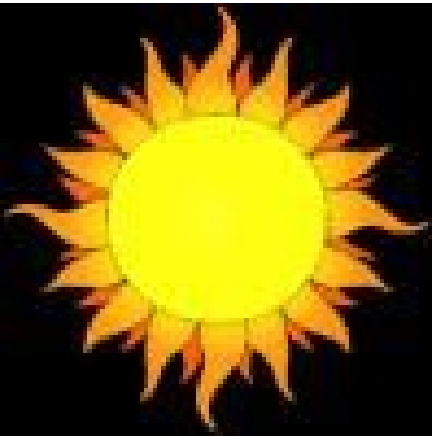


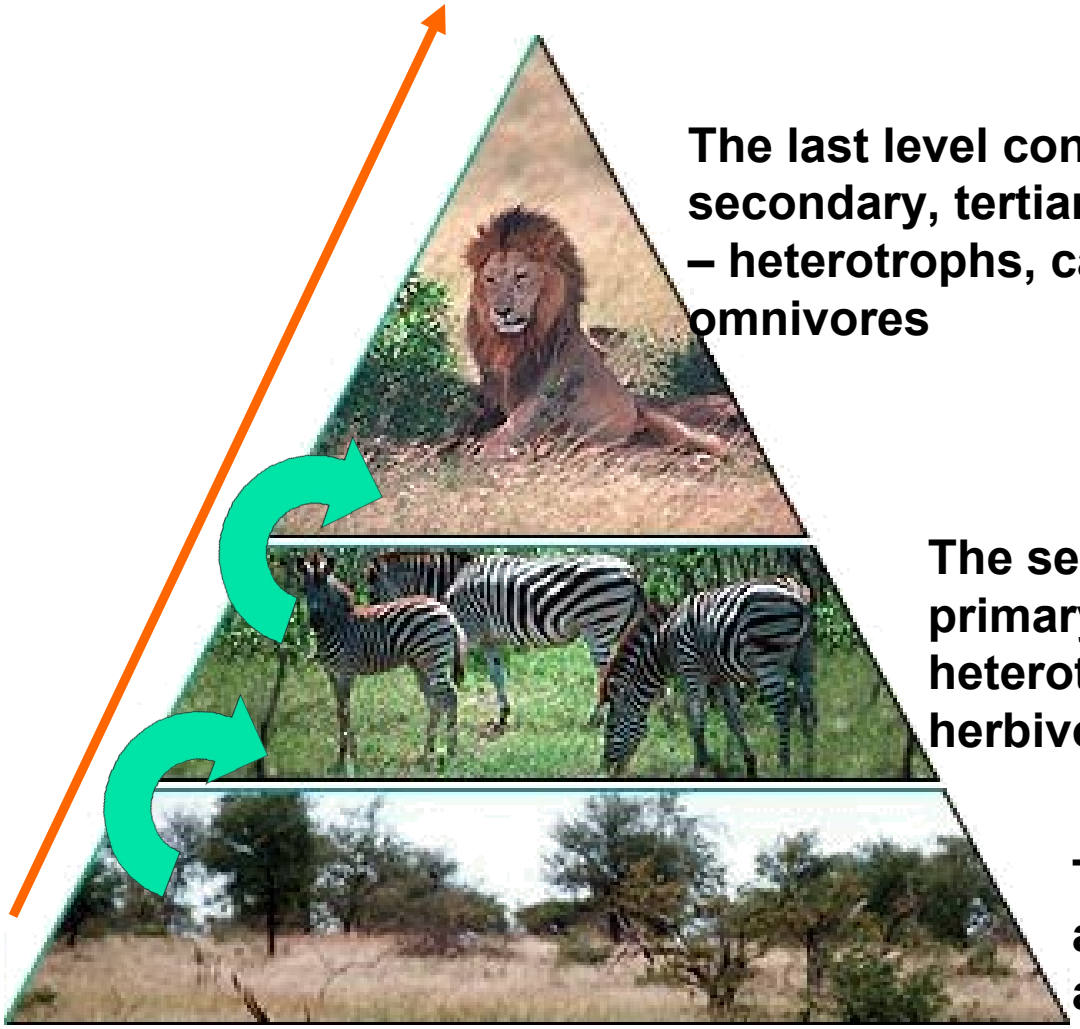
Flow of energy:- Autotrophic plant change radiant energy into chemical energy through photosynthesis. Part of this energy is consumed by autotrophs during their respiration, growth and other metabolic reaction. Other organism will get energy from autotrophs, where organic compounds are used in body building and energy is used for growth and maintenance. The flow of energy in ecosystem is uni direction ie, from producers to living organism and energy is losing when it transfer from one organism to another.

With each trophic transfer, some usable energy is degraded and lost to the environment as low quality heat. Thus, only a small portion of what is eaten and digested is actually converted into an organisms.



Energy is eventually lost as heat on the top of the pyramid





The last level contains secondary, tertiary consumers – heterotrophs, carnivores, omnivores

The second level has primary consumers – heterotrophs, herbivores.

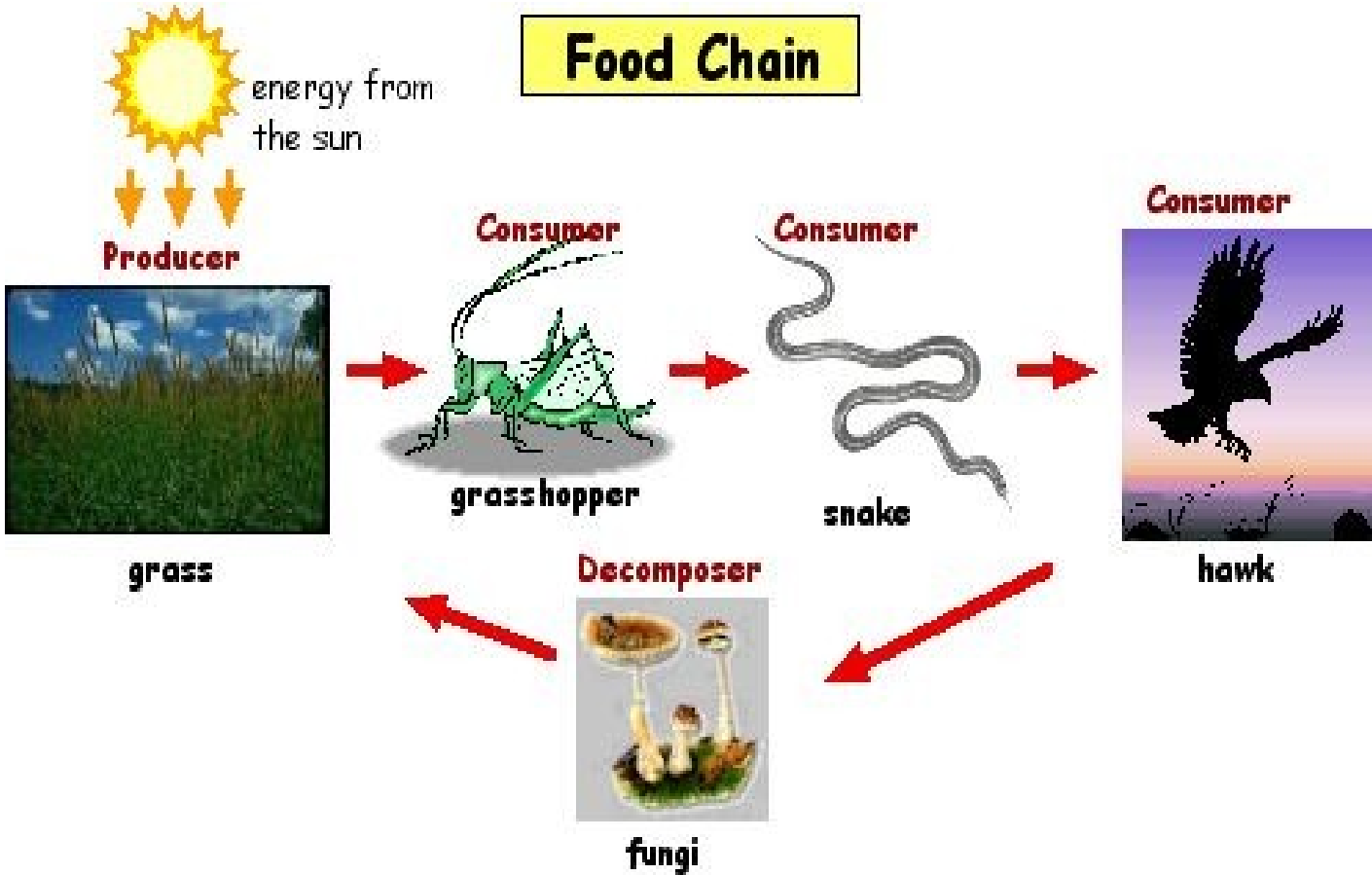
The first level always has autotrophs

- **Interrelation:-** Different ecosystems exchange biotic and abiotic materials. Eg: Plants provide O_2, food, shelter to animals and animals will supply CO_2 to plants. Animals are also interrelated in food web to become the food of another.
- **Cybernetics**:- Ecosystem maintain a functional balance between various components. It is achieved by a number of limitations, which is called cybernetics. Eg:- species control depend on scarcity of resources, recycling of waste by environment (self regulation), one living component can control other through feed back system (when number of zooplankton increases it decreases the number of phytoplankton which result in reduction of zooplankton .

A **food chain** describes a ingle pathway that energy and utrients may follow in an cosystem. They usually start ith a primary producer and end ith a top predator.

FOOD CHAIN

Food chains/webs show how matter and energy move from one organism to another through an ecosystem



Types of food chains

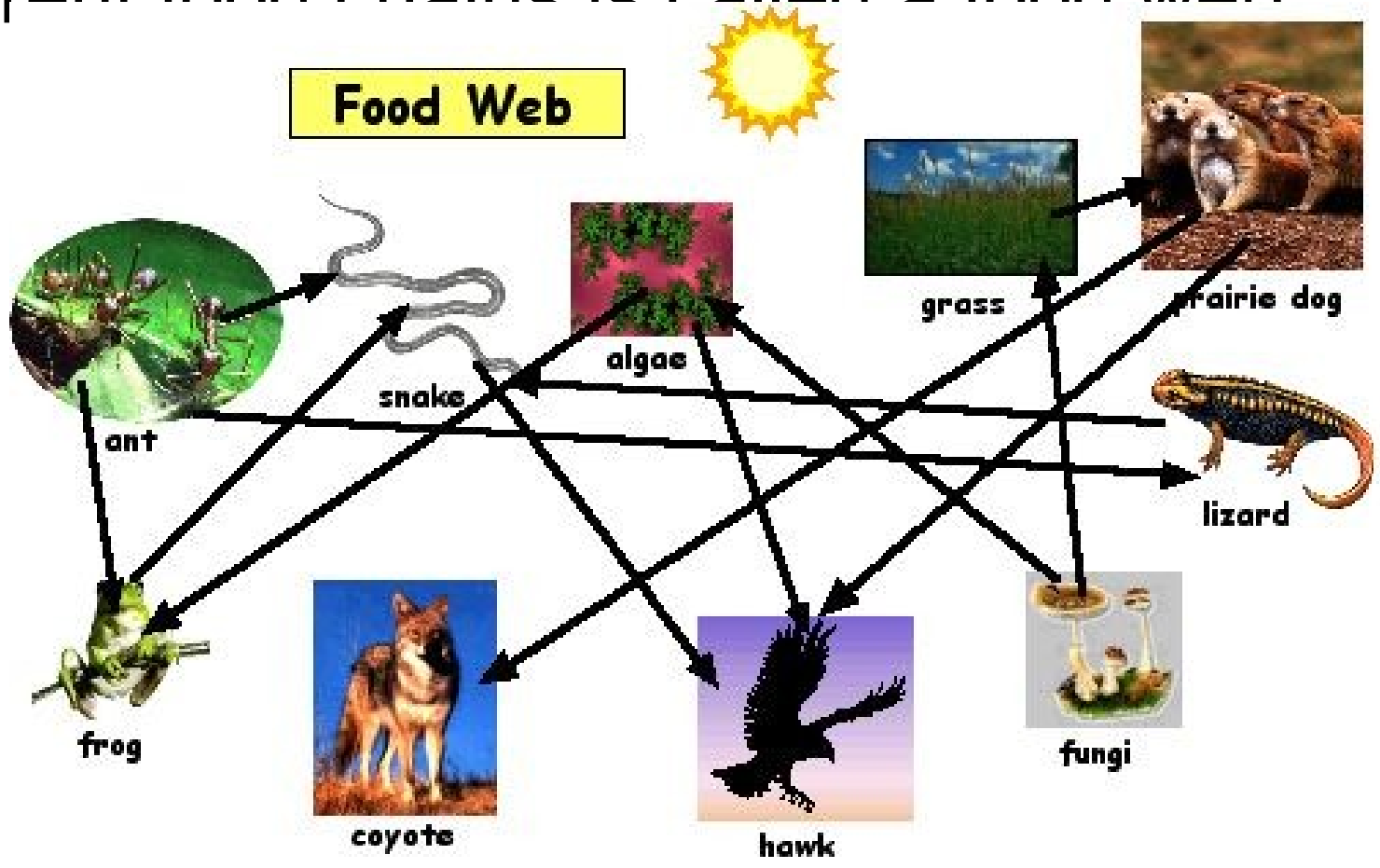
1. **Grazing food chain:** It starts with green plants (primary producers) and culminates in carnivores. Example :

- Grass —> Rabbit —> Fox
- Phytoplankton —> Zooplantkton —> Fish —> Man

2. **Detritus food chain:** It starts with dead organic matter which the detritivores and decomposers consume. Partially decomposed dead organic matter and even the decomposers are consumed by detrivores and their predators. **Example** -Dead organic matter —> Detrivores —>predators.

FOOD WEB

Some organisms eat a variety of other organisms, then food chain become complex. A combination of different food chains is called a food web



ECOLOGICAL PYRAMIDS

An ecological pyramid is a diagram that shows the number of organisms, energy relationships, and biomass of an ecosystem.

Food chains and food webs do not give any information about the numbers of organisms involved.

They are

1.Pyramid of Biomass

2.Pyramid of Energy

3.Pyramid of Numbers

Ecological Pyramid of Energy –

show the energy flow through an ecosystem

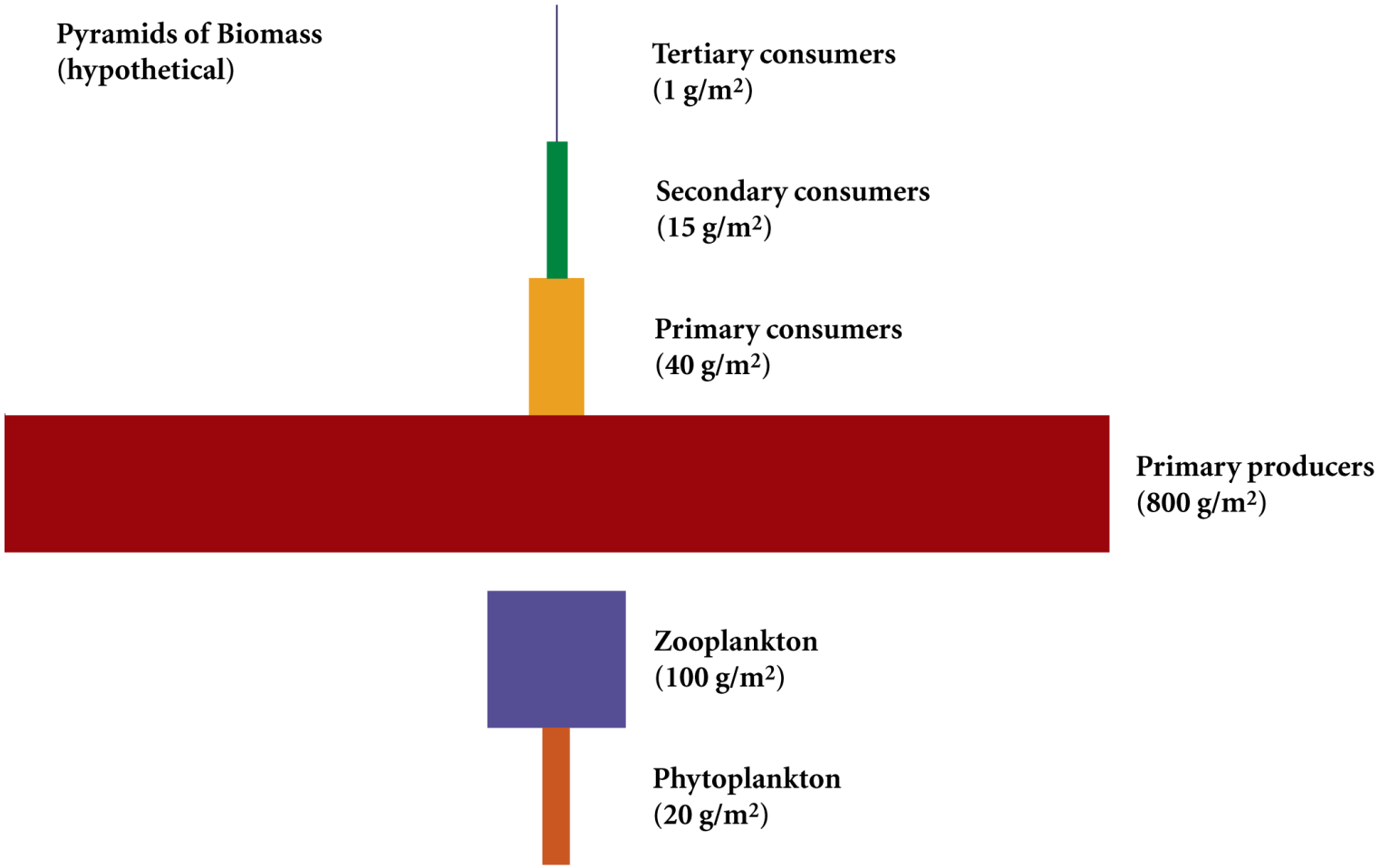
The energy pyramid will always be upright because there is always gradual decrease in the energy content at successive trophic level from producers to consumers because one part of energy is used for metabolic process, growth etc.. Remaining part is transferred to other level.

At the producer level the total energy will be much greater than the energy at the successive higher trophic level.

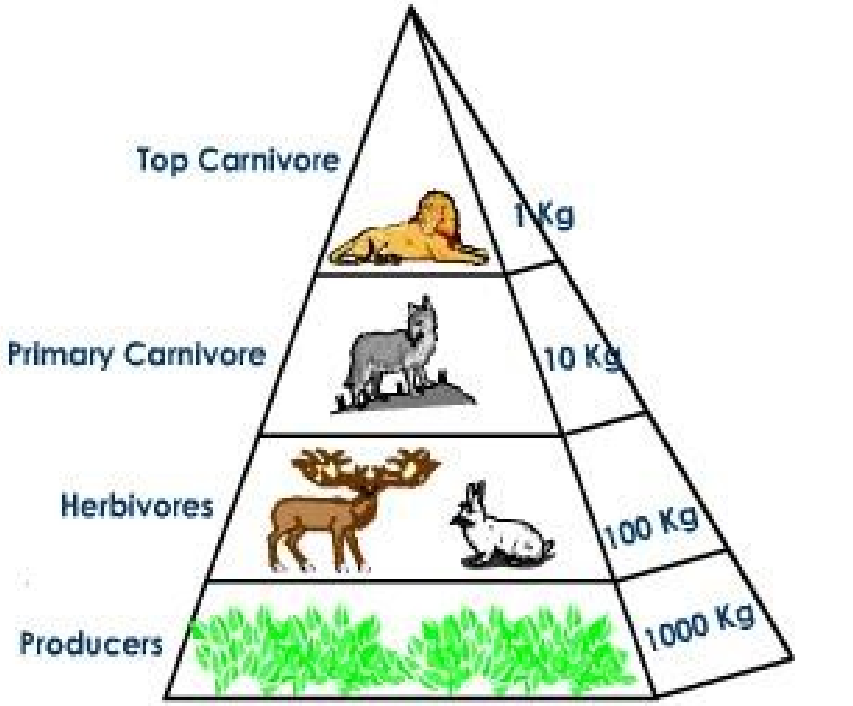
Ecological Pyramids of Biomass

The pyramid of biomass is two types. If a larger weight of producers support a smaller weight of consumers, results an upright pyramid (grass ecosystem) and if a smaller weight of producers support a larger weight of consumers, an inverted biomass pyramid results (aquatic ecosystem). In the example, phytoplankton grow and reproduce so rapidly that they can support a large population of zooplankton even though the biomass of phytoplankton is smaller than that of the zooplankton.

Ecological Pyramids of Biomass

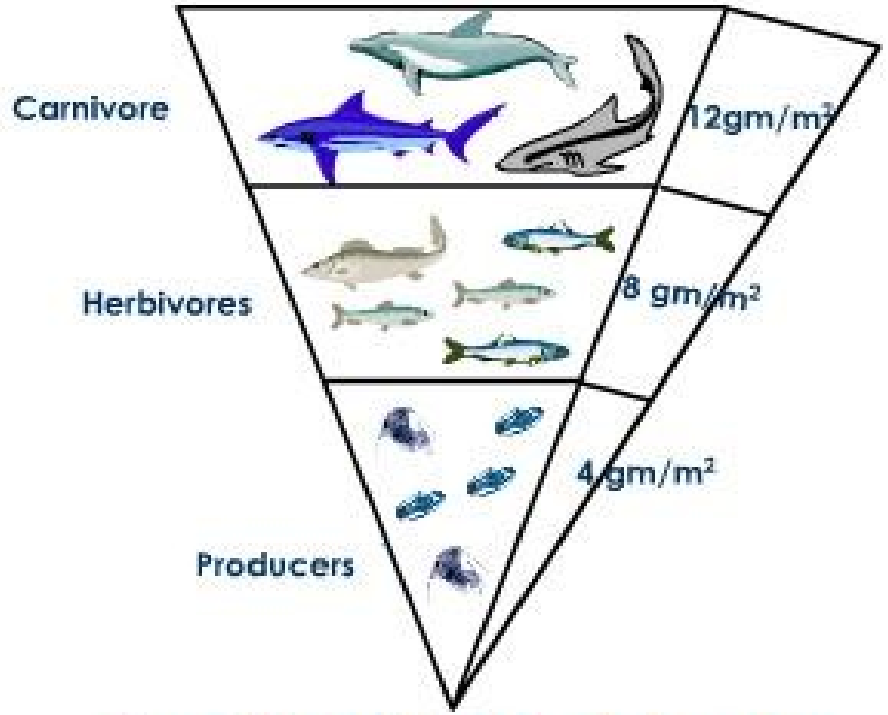


Pyramids of Biomass



Upright Pyramid of biomass in a Terrestrial Ecosystem

Upright



Inverted Pyramid in an Aquatic Ecosystem

Inverted

Ecological Pyramids of Numbers

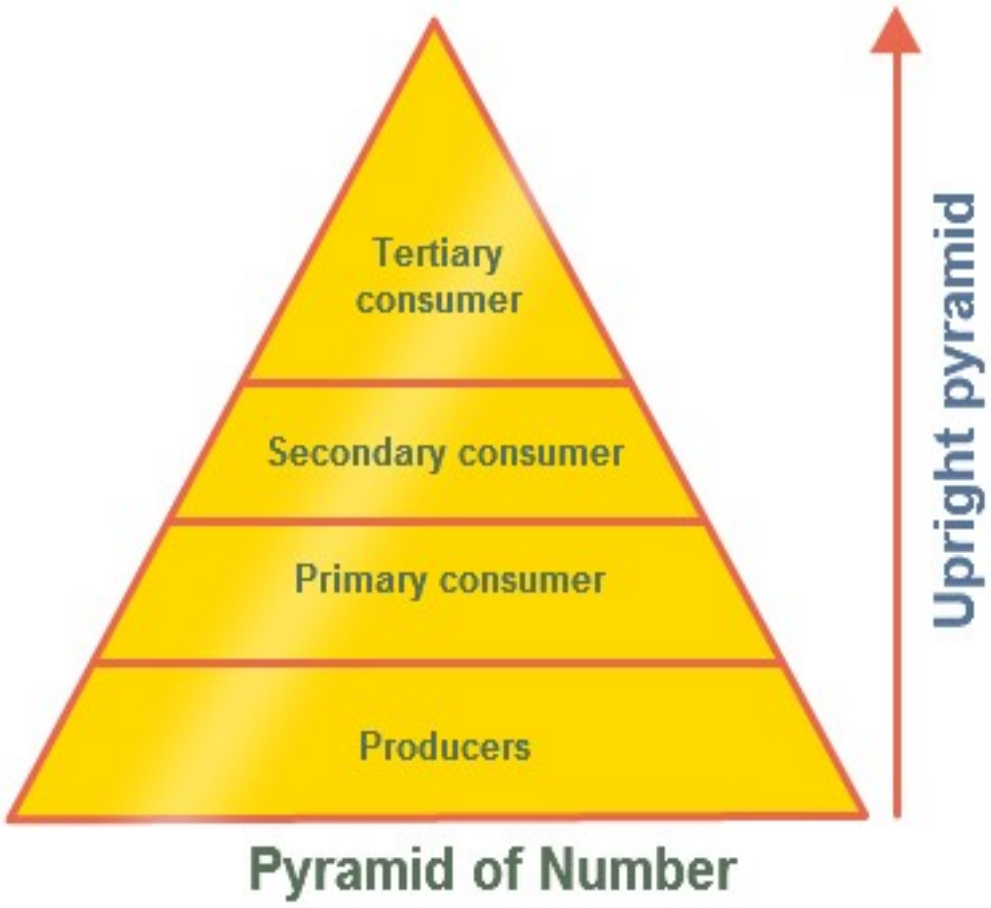
This shows the relationship among the number of producers and consumers. It also show the number of individuals per unit area of each trophic level. The structure and shape of pyramid will vary from one ecosystem to other.

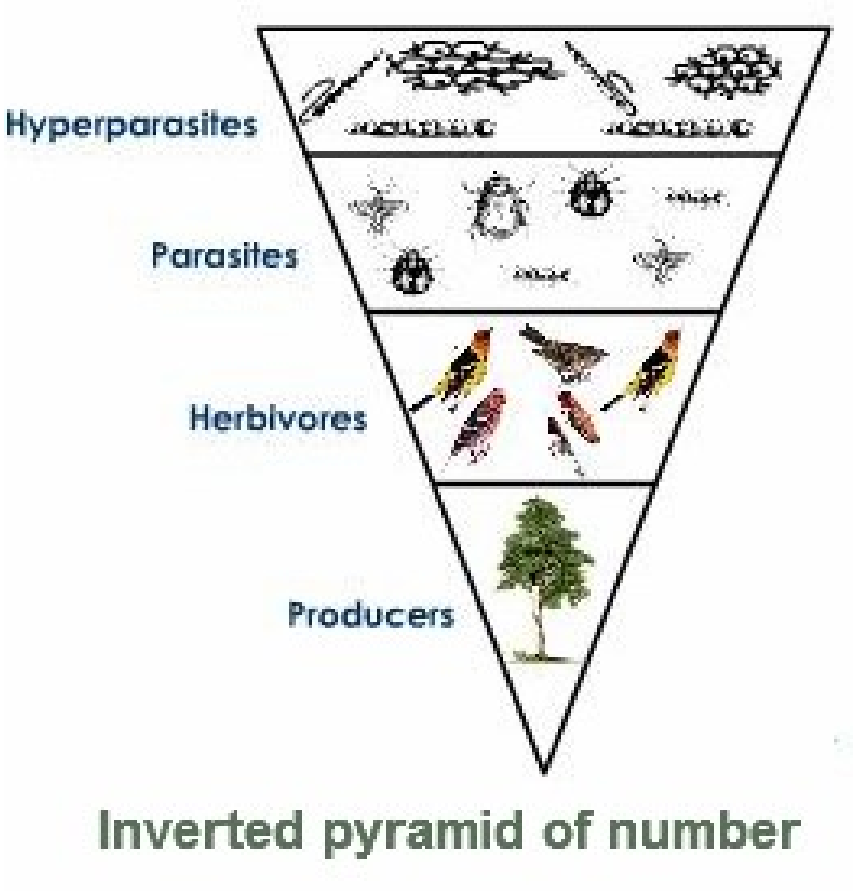
G**rass land ecosystem**- Producers (grasses large in number), primary consumers (rabbit, mice etc. less in number compared to plants), secondary consumers are much lesser (lizard, snake etc..). Thus the **pyramid is upright**.

Aquatic ecosystem – Producers (algae large in number), primary consumers (small fishes less in number compared to algae) and secondary consumers (birds less in number etc..). This will also give **upright pyramid**.

But in **parasite food chain pyramid is inverted**. Single large tree can support many fruit eating birds. This each bird support the growth of large number of parasites. Thus the number of organism gradually increased from first trophic level to last.

Ecological Pyramids of Numbers





In grass land and aquatic ecosystem

In parasite food chain

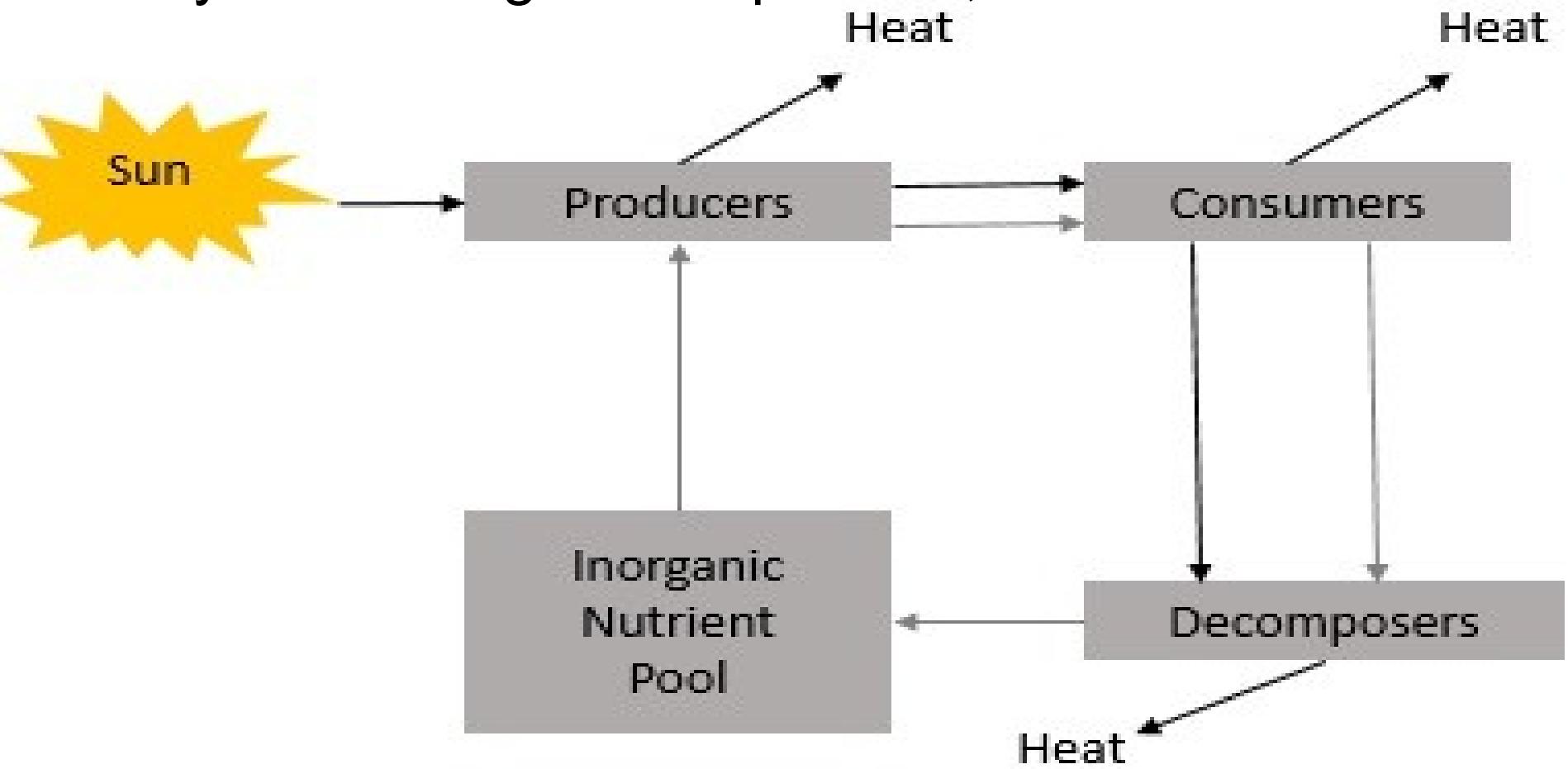
FLOW OF ENERGY

- The cycle of energy is based on the flow of energy through different trophic levels in an ecosystem. Our ecosystem is maintained by the cycling energy and nutrients obtained from different external sources.
- At the first trophic level, primary producers use solar energy to produce organic material through photosynthesis. The herbivores at the second trophic level, use the plants as food which gives them energy. A large part of this energy is used up

for the metabolic functions of these animals such as breathing, digesting food, supporting growth of tissues, maintaining blood circulation and body temperature.

- The carnivores at the next trophic level, feed on the herbivores and derive energy for their sustenance and growth. If large predators are present, they represent still higher trophic level and they feed on carnivores to get energy.

- Decomposers break down wastes and dead organisms, and return the nutrients to the soil, which is then taken up by the producers. Energy is not recycled during decomposition, but it is released.



BIOGEOCHEMICAL CYCLES

- Biogeochemical cycles refer to the flow of elements and compounds between organisms and the physical environment.
- Chemicals taken in by organisms are passed through the food chain and come back to the soil, air, and water through mechanisms such as respiration, excretion, and decomposition. Such cyclic exchange of material between the living organisms and their non-living environment is called Biogeochemical Cycle.

Following are some important biogeochemical cycles −

Carbon Cycle

Nitrogen Cycle

Oxygen Cycle

Phosphorus Cycle

Sulphur Cycle

Hydrological cycle

CARBON CYCLE

- Carbon used to constitute almost all organic compounds of the cell such as carbohydrates, proteins, lipids, enzymes, nucleic acids, hormones etc.
- Together, photosynthesis and cellular respiration form the basis of the carbon cycle.

Photosynthesis: in which algae, higher plants, and photosynthetic bacteria use light energy to fix inorganic carbon in a high-energy organic form:

$$CO_2 + H_2O \rightarrow \{CH_2O\} + O_2(g)$$

- In atmosphere and hydrosphere carbon content is maintained because of its return through 2 major processes

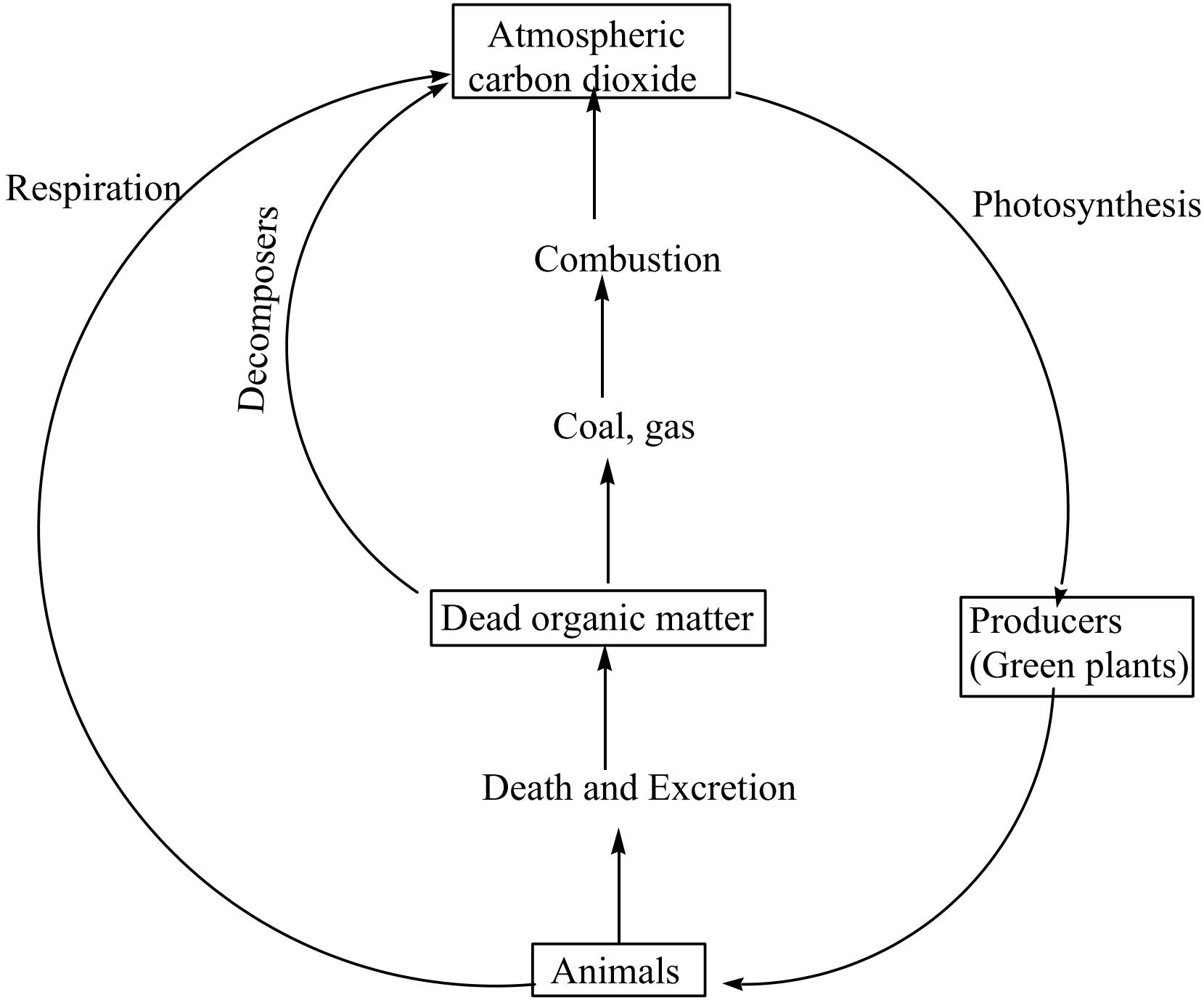
(1) Biological respiration and decomposition of organic matter

(2) Non biological combustion of fuel that further releases CO_2 in the atmosphere.

In this way carbon is fixed on earth and returned to atmosphere again.

- Carbon cycle was almost a perfect cycle. But now carbon has been added to the atmosphere faster than producers can remove it. Also, deforestation reduces the amount of carbon dioxide being used in photosynthesis. Further, the use of land for agriculture releases carbon dioxide into the environment.

Plants in water need carbon dioxide to perform photosynthesis and release oxygen. Fish use the oxygen to breathe and the plants for food. Thus, fish depend on the carbon dioxide cycle.


Atmospheric carbon dioxide
Respiration
Decomposers
Combustion
Photosynthesis
Coal, gas
Dead organic matter
Producers (Green plants)
Death and Excretion
Animals

NITROGEN CYCLE

- Nitrogen Cycle is a biogeochemical process which transforms the inert nitrogen present in the atmosphere to a more usable form for living organisms.

Processes:

- Nitrogen fixation
- Ammonification
- Nitrification
- Denitrification

Nitrogen fixation

Atmospheric nitrogen is converted into useful nitrate form by a process known as nitrogen fixation

(i)Biological (living) nitrogen fixation: It involves the transformation of atmospheric nitrogen into nitrites and nitrates by living organisms. It is brought about by certain bacteria. Rhizobium associated with nodules of legume family plants have ability to convert atmospheric N_2 into NH_3 to synthesize aminoacids, proteins in plant cells.

This usable nitrate form is transferred to herbivores and carnivores through food chain

$N_2 \rightarrow NH_3 \rightarrow$ Aminoacids $\rightarrow$ Proteins

(ii)Atmospheric (nonliving) nitogen fixation:

(a)Industrial fixation: Haber's process- N_2 and H_2 are reacted under high P and T in the presence of catalyst to produce NH_3 which may be used as fertilizer

(b) Photochemical and electrochemical fixation:O_2 combine with N_2 to form nitrogen oxides (Nox).

These oxides dissolved in water to form nitrous acid and nitric acid ormay be combine with salt to produce nitrates.

Ammonification

It involves the decomposition of proteins of dead plants and animals and nitrogenous waste into ammonia in presence of ammonifying bacteria.

Proteins (dead plants and animals)→ Amino acids → Ammonia

Nitrification

It involves oxidation of ammonia to nitrates through nitrites in presence of nitrifying bactria

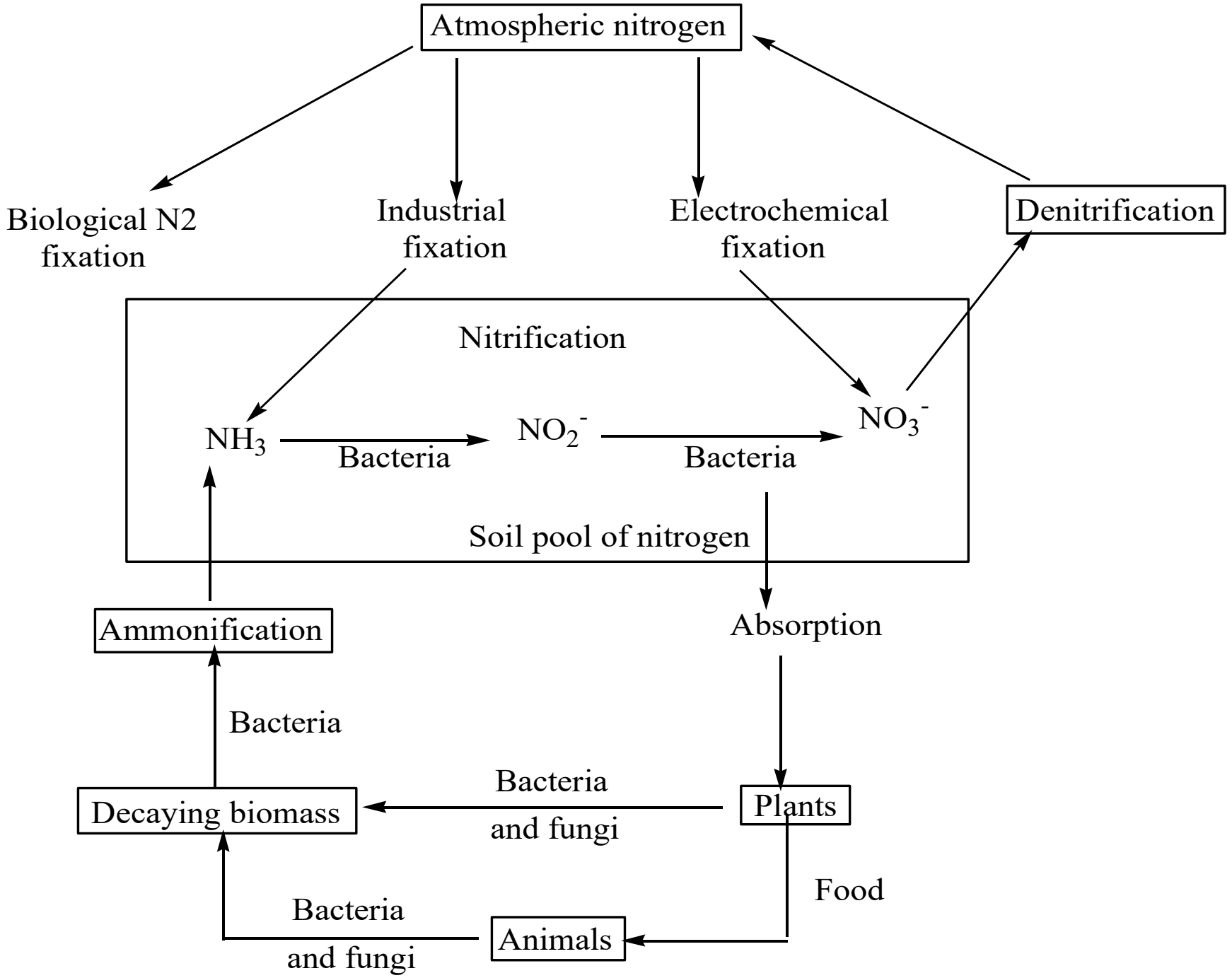
$NH_3 \rightarrow NO_2^- \rightarrow NO_3^-$

Denitrification

- It is a biological process in which ammonium compounds are reduced to molecular nitrogen in presence of denitrifying bacteria under anaerobic conditions.

$$NO_3^-, NO_2^-, NO \xrightarrow{\text{denitrifying bacteria}} N_2$$

- This nitrogen is slowly released back to atmosphere to maintain nitrogen concentration constant and the cycle gets completed.


Atmospheric nitrogen
Biological N2 fixation
Industrial fixation
Electrochemical fixation
Denitrification
Nitrification
NH_3
Bacteria
NO_2^-
Bacteria
NO_3^-
Soil pool of nitrogen
Ammonification
Absorption
Bacteria
Bacteria and fungi
Decaying biomass
Plants
Food
Bacteria and fungi
Animals

PHOSPHOROUS CYCLE

- Phosphorous are essential nutrients for growth and maintenance of animal bones and teeth while organo-phosphates are required for cell division involving the production of nuclear DNA and RNA

Sources:

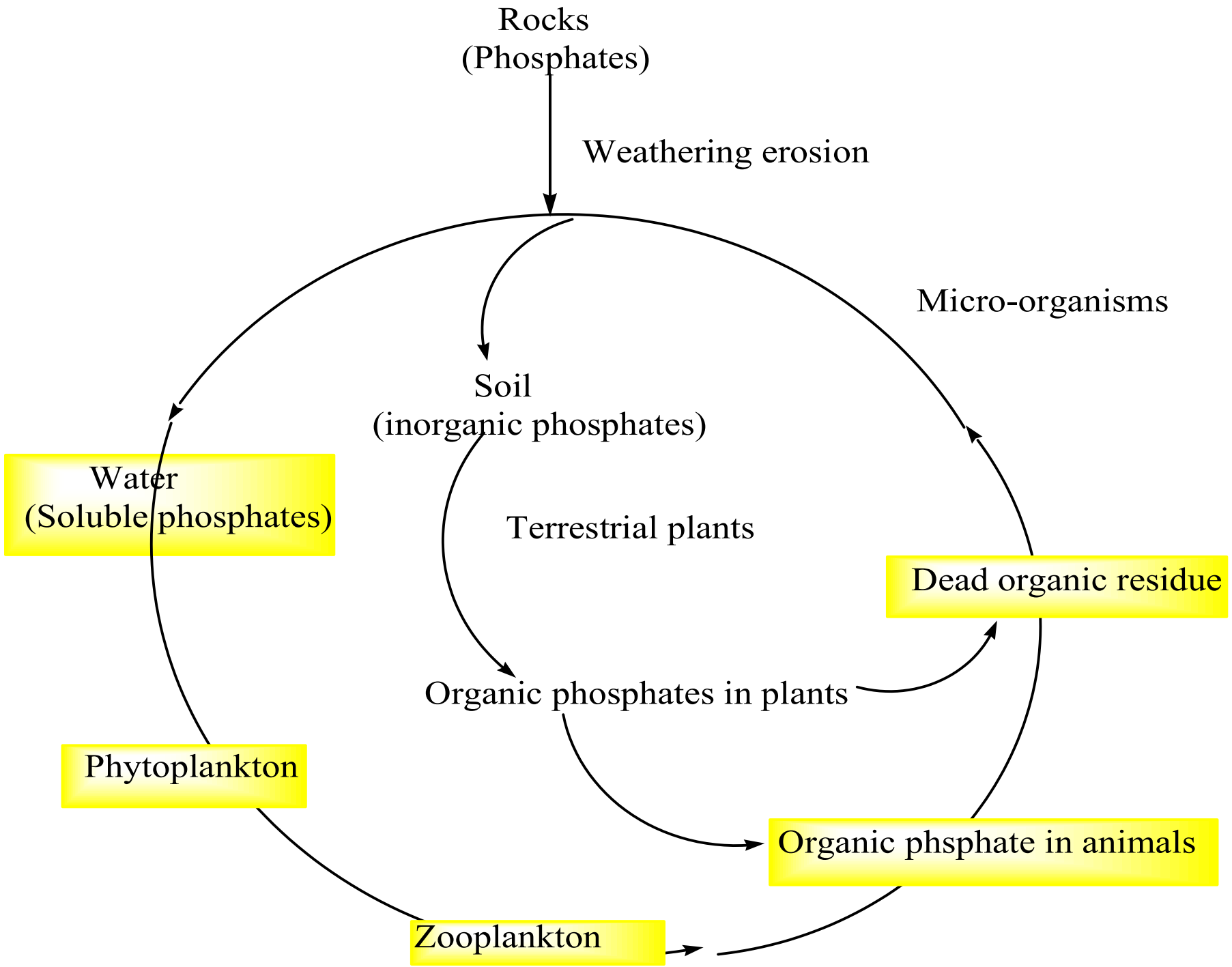
Natural: Phosphate minerals are located in rock and soil where phosphate exist in soluble and insoluble forms.

Artificial: Human activities

Processes:

- Phosphorous cycle contains terrestrial and aquatic processes. Phosphorous containing rocks are broken down by rock weathering, chemical reaction and eroding action of wind and moving water. Some of the part become dissolved in water as phosphate and other particles become part of soil. Terrestrial plants and bacteria absorb inorganic phosphate salt from soil and convert these into organic phosphates.

Phosphorous moves from plants to animals of different trophic levels in ecosystem through food chains. After their death and decay, phosphorous present in plants and animals (organic form) is returned to soil and water (inorganic form) through decomposition dead remains by microorganisms; to be reused by plants. In this way phosphorous is recycled.


Rocks
(Phosphates)
Weathering erosion
Micro-organisms
Soil
(inorganic phosphates)
Water
(Soluble phosphates)
Terrestrial plants
Dead organic residue
Organic phosphates in plants
Phytoplankton
Organic phsphate in animals
Zooplankton

SULPHUR CYCLE

- Sulphur is an essential part of protein and aminoacids. It exist in nature as: elmental sulphur, sulphides and sulphates.

Sources:

Atmosphere: SO_2, H_2S, SO_3

Natural emission: sources that emit sulphur directly into atmosphere such as volcanic eruption etc.

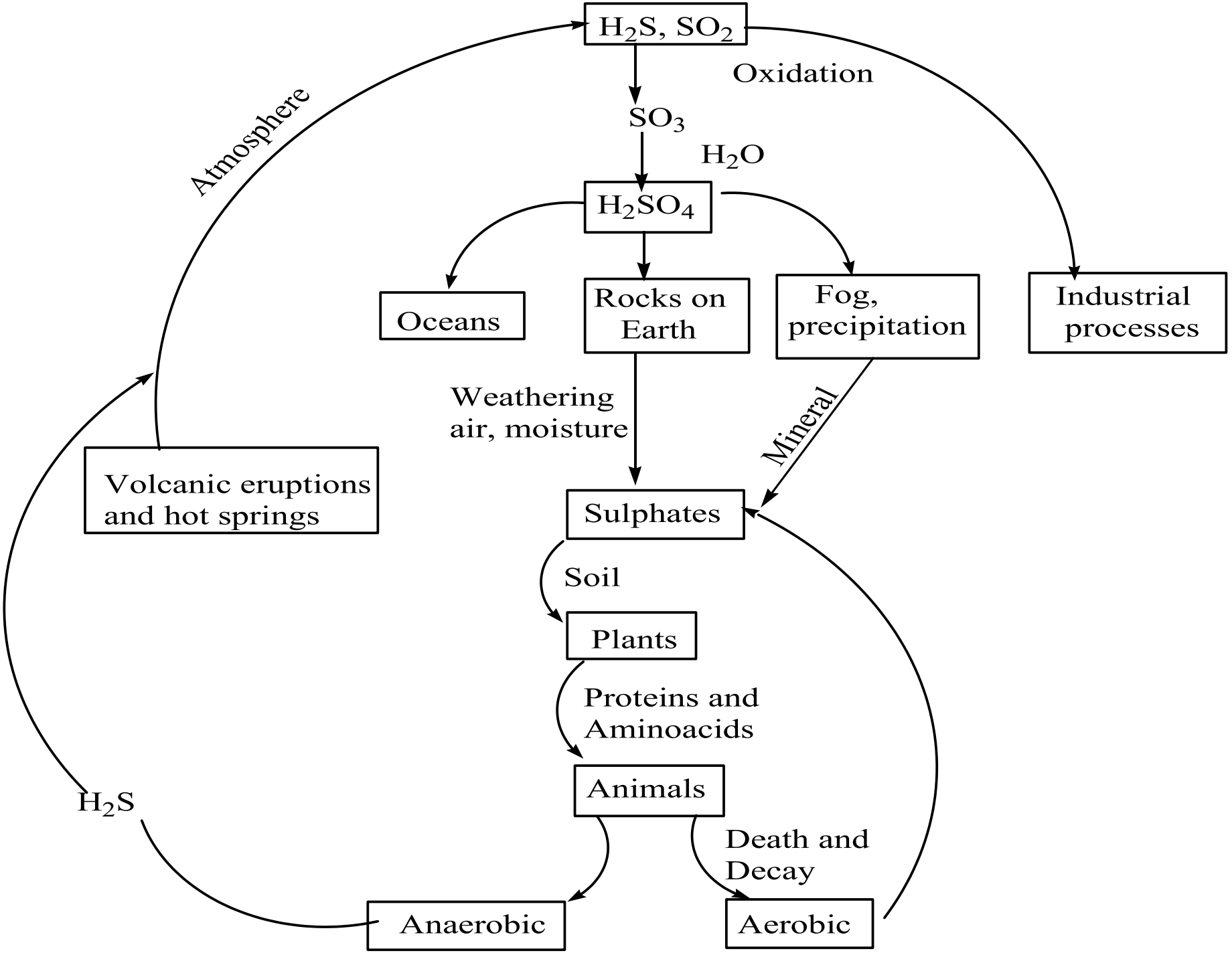
Artificial: Combustion of fuel

Hydrocarbons (containing S) $\longrightarrow$ $CO_2 + H_2O +$ SOx

Processes:

Cycle begins with weathering of rocks, releasing stored sulphur. This S comes in contact with air where it is converted into sulphate in presence of moisture. Sulphur in soluble form, mostly as sulphate is absorbed through plants, where it is incorporated into certain organic molecule such as aminoacids and proteins. From the producers, the sulphur in aminoacids transferred to the consumerswith excess being excreted in faeces. Excretion and death carry

sulphur in living material back to soil where ythe organic material acted upon by the bacteria of dentritus food chain. Again sulphur produced that can be reused by autotrophs and the cycle goes on.


H_2S, SO_2
Oxidation
SO_3
H_2O
H_2SO_4
Atmosphere
Oceans
Rocks on Earth
Fog, precipitation
Industrial processes
Weathering air, moisture
Mineral
Volcanic eruptions and hot springs
Sulphates
Soil
Plants
Proteins and Aminoacids
Animals
H_2S
Death and Decay
Anaerobic
Aerobic

OXYGEN CYCLE

- Major component needed by the most plants, animals and man for aerobic respiration or enzymatic oxidation of organic food is oxygen.

Production of $O_{2:-}$

(a)Photosynthesis: $CO_2 + H_2O \xrightarrow{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$

(b)Photodissociation: High energy UV radiation break down the atmospheric water and nitrogen oxide to provide oxygen.

$H_2O \xrightarrow{UV} 2H + O_2$; $2N_2O \xrightarrow{UV} 4N + O_2$

Oxygen consumption:

(a)Respiration and natural decay: As a constituent of CO_2, it circulates freely throughout the biosphere

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

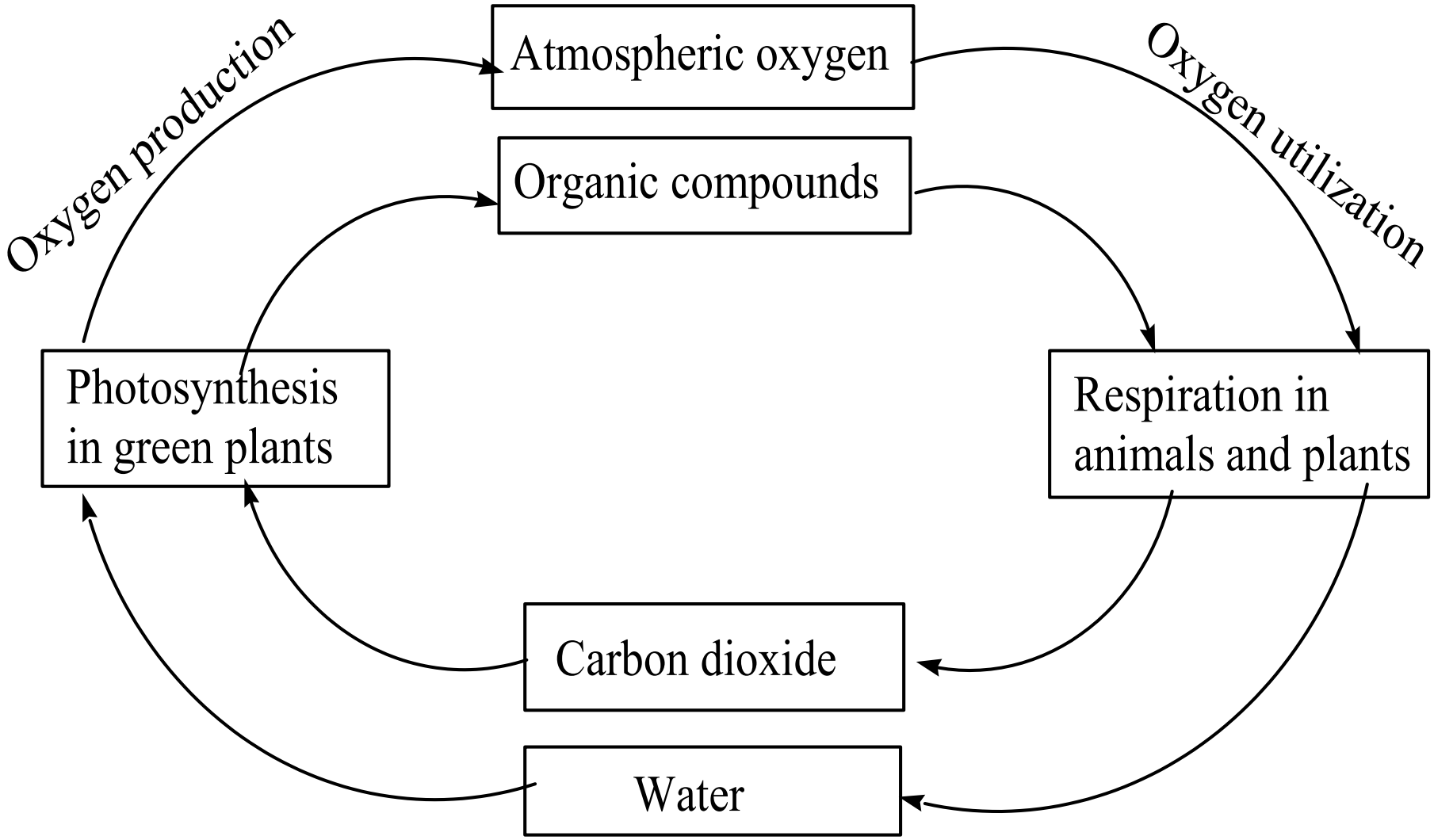
(b) Combustion reaction: Burning of fossil fuel

$$C + O_2 \longrightarrow CO_2$$

(c) Oxidation weather process: O_2 is consumed in natural oxidation of some oxidative weathering process of minerals in earth crust

$$4FeO + O_2 \longrightarrow 2Fe_2O_3$$

It is again made available to the environment in combination with carbon in the form of CO_2 or with hydrogen as H_2O. Oxygen is also released as a part of CO_2 due to death and decay of organic matter. In such a vital cycle, O_2 is replenished and maintained in the ecosystem.


Atmospheric oxygen
Organic compounds
Photosynthesis in green plants
Respiration in animals and plants
Carbon dioxide
Water
Oxygen production
Oxygen utilization

HYDROLOGICAL CYCLE

- Water or hydrological cycle involves, the circulation of water and moisture among air, land, sea and living organisms

Mainly 2 cycles

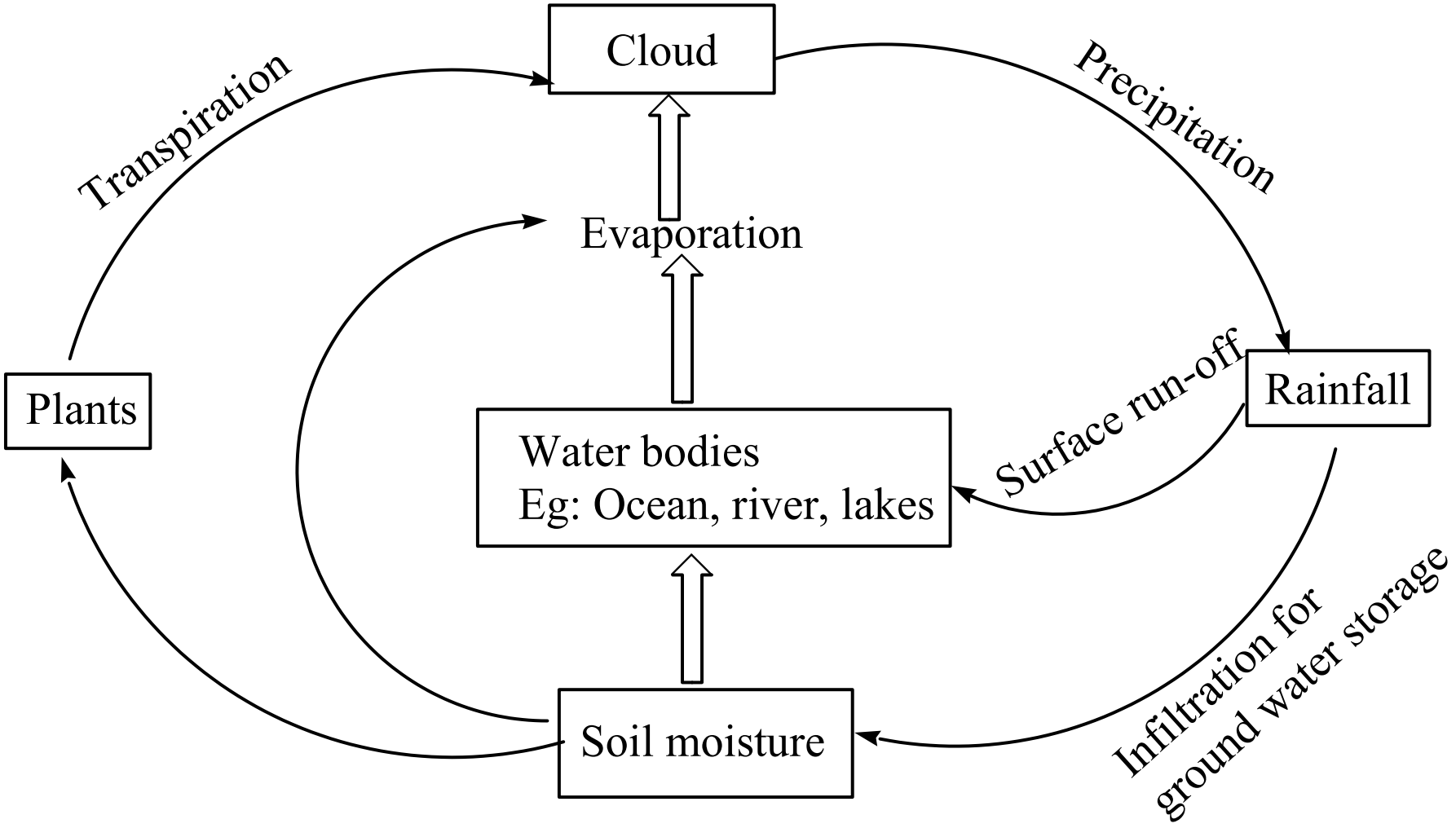
1)Larger global cycle: in which living organisms are not involved. It include

Evaporation: Evaporation of water by solar energy

Cloud formation: Clouds are formed by cooling and condensation of water vapours

Precipitation: Clouds get cooled and precipitated as rain or snow

2) Local or biological cycle: It involves entry of water to the living organisms and its return to the atmosphere. Large amount of rain water goes into soil which is extracted by plants through their roots. Another route for cloud formation is called transpiration, in which water from plants get converted into clouds. This combined process is called evapotranspiration


Cloud
Transpiration
Precipitation
Evaporation
Plants
Rainfall
Surface run-off
Water bodies
Eg: Ocean, river, lakes
Soil moisture
Infiltration for
ground water storage

BIOACCUMULATION

- Accumulation of pollutants in an organism over its life span
- Can occur whenever the half-life of the pollutant is greater than the life span of the organism
- Seen at all levels of a food chain with continual exposure to a chemical

Examples: atrazine in amphibians, most chemical exposure in humans

Why it is important to study:

1.Enhance the persistence of industrial chemicals in the ecosystem

2.Stored chemicals are not exposed to direct physical, chemical, or biochemical degradation.

3.Stored chemicals can directly affect an individual's health.

4.Predators of those organisms that have bio-accumulated harmful substances may be endangered by food chain effects.

BIOMAGNIFICATION

Biomagnification stands for Biological Magnification, which means the increase of contaminated substances or toxic chemicals that take place in the food chains.

- accumulation of pesticides across trophic levels (up a food chain)
- observed mostly in top predators

Examples: lead in California Condors, mercury in billfish, rodent killer in coyotes and mountain lions

When an animal consumes food having DDT residue, the DDT accumulates in the tissue of the animal by a process called bioaccumulation. The higher an animal is on the food chain (e.g. tertiary consumer such as seals), the greater the concentration of DDT in their body as a result of a process called biomagnification.

Bioaccumulation is the concentration of pollutant from the environment which occurs within a trophic level, ie. One level of a food chain

Biomagnification is the concentration of pollutant across the food chain

ECOSYSTEM VALUES:

1. Direct value: Resources that people depend upon directly

- Consumptive use value: Non-market value of fruit etc. that are used by people who collect them from their surroundings
- Productive use value: Commercial value of fish, medicinal plants etc. that people collect for sale.

2. Indirect value: These are uses that do not have easy ways to quantify them in therms of a clearly definable price.

- Non-consumptive use value- bird watching, scientific research, tourism etc.
- Option value – maintaining options for the future, so that by preserving them one could reap economic benefits in the future
- Existence value – ethical and emotional aspects of the existence of wildlife and nature

ECOSYSTEM SERVICES:

1. Purification and Detoxification (of air, water and soils)

2. Cycling Processes: (nutrient cycling, nitrogen fixation, carbon sequestration, soil formation)

3. Regulation and Stabilisation: pest and disease control, climate regulation, mitigation of storms and floods, erosion control, regulation of rainfall and water supply;

4. Habitat Provision: refuge for animals and plants, storehouse for genetic material;

5. Regeneration and Production: production of biomass providing raw materials and food, pollination and seed dispersal; and
6 Information/Life-fulfilling: aesthetic, recreational, cultural and spiritual role, education and research. Some further examples of these services are provided below.

CARRYING CAPACITY OF AN ECOSYSTEM

In ecological terms, the carrying capacity of an ecosystem is the size of the population that can be supported indefinitely upon the available resources and services of that ecosystem.

It depends on many abiotic and biotic factors in the ecosystem. For example, the availability of the basic needs of organisms such as food, water and shelter dictates how many individuals the ecosystem can sustain. This process is self-regulating to some extent

because individuals will die when the carrying capacity is exceeded.

Other factors that influence the carrying capacity of an ecosystem include disease, predator-prey interactions, the consumption rate of resources and the number of populations in the ecosystem. However, there are other factors that are hidden, less obvious and/or disregarded which have a significant impact on populations such as pollution, eradication of habitat and climate change.