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DEPARTMENT OF BIOLOGICAL SCIENCES

INTRODUCTORY ECOLOGY

(BIO 202)

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COURSE OUTLINE

- Concept and definition of ecosystem.
- Community ecology.
- Ecological classification of habitats; Terrestrial and aquatic biomes.
- Ecological factors affecting plants and animals in each biome.
- Productivity.
- Energy flow and nutrient cycle.
- Natural destruction factors.
- Dynamics of population.
- Succession.

CONCEPT AND DEFINITION OF ECOSYSTEM.

Ecology is the science that deals with the relationships between living organisms with their physical environment and with each other. Ecology can be approached from the viewpoints of the environment and the demands it places on the organisms in it or organisms and how they adapt to their environmental conditions.

For the study of ecology it is often convenient to divide the environment into four broad categories.

1. Terrestrial environment - The terrestrial environment is based on land and consists of biomes, such as grasslands, one of several kinds of forests, savannas, or deserts.
2. Freshwater environment - The freshwater environment can be further subdivided between *standing-water habitats (*lakes, reservoirs) and *running-water habitats (*streams, rivers).
3. Oceanic marine environment - The oceanic marine environment is characterized by saltwater and may be divided broadly into the shallow waters of the continental shelf composing the neritic zone.

Structure and Function of an ecosystem

An ecosystem has two components:

1. the biotic components consisting of living things: The living organisms may be sub divided into producers, consumers and decomposers.
2. the abiotic portion, consisting of elements that are not alive. The non living constituents are said to include the following category, habitat, gases, solar radiation, temperature, moisture and inorganic and organic nutrients. Abiotic Components include basic inorganic and organic components of the environment or habitat of the organism. The inorganic components of an ecosystem are carbon dioxide, water nitrogen, calcium phosphate all of which are involved in matter cycle (biogeochemical cycles). The organic components of an ecosystem are proteins, carbohydrates, lipids and amino acids, all of which are synthesized by the biota (flora and fauna) of an ecosystem and are reached to ecosystem as their wastes, dead remains etc. the climate 'microclimate'

temperature, light soil etc. are abiotic components of the ecosystems.

Functions of an Ecosytem

Ecosystem function is the capacity of natural processes and components to provide goods and services that satisfy human needs, either directly or indirectly. Ecosystem functions are subset of ecological processes and ecosystem structures. Each function is the result of the natural processes of the total ecological sub-system of which it is a part. Natural processes, in turn, are the result of complex interactions between biotic (living organisms) and abiotic (chemical and physical) components of ecosystems through the universal driving forces of matter and energy. **There are four primary groups of ecosystem functions** (1) regulatory functions, (2) habitat functions, (3) production functions and (4) information functions. This grouping concerns all ecosystems, not only for forests.

Components of an ecosystem: Complete ecosystem consists of four basic components such as producers, consumers, decomposers and abiotic components e.g. Pond. If anyone of these four components are lacking, then it is grouped under incomplete ecosystem e.g. Ocean depth or a cave.

An understanding of ecology is essential in the management of modern industrialized societies in ways that are compatible with environmental preservation and enhancement. The branch of ecology that deals with predicting the impacts of technology and development and making recommendations such that these activities will have minimum adverse impacts, or even positive impacts, on ecosystems may be termed as Applied Ecology. It is a multidisciplinary approach .

Interactions among living organisms are grouped into two major groups *viz*.,

- Positive interactions
- Negative interactions

I. **Positive interactions**

Here the populations help one another, the interaction being either one way or reciprocal. These include (i) Commensalism, (ii) Proto co-operation and (iii) mutualism.

Commensalism

In this one species derives the benefits while the other is unaffected.

Eg. (i) Cellulolytic fungi produce a number of organic acids from cellulose which serve as carbon sources for non-cellulolytic bacteria and fungi.

(ii) Growth factors are synthesised by certain microorganisms and their excretion permits the proliferation of nutritionally complex soil inhabitants.

1. **Proto-cooperation**

It is also called as non-obligatory mutualism. It is an association of mutual benefit to the two species but without the co-operation being obligatory for their existence or for their performance of reactions.

Eg. N_2 can be fixed by *Azotobacter* with cellulose as energy source provided that a cellulose decomposer is present to convert the cellulose to simple sugars or organic acids.

2. Mutualism

Mutually beneficial interspecific interactions are more common among organisms. Here both the species derive benefit. In such association there occurs a close and often permanent and obligatory contact more or less essential for survival of each.

Eg. (i) Pollination by animals. Bees, moths, butterflies etc. derive food from hectar, or other plant product and in turn bring about pollination.

(ii) Symbiotic nitrogen fixation: Legume - *Rhizobium* symbiosis. Bacteria obtain food from legume and in turn fix gaseous nitrogen, making it available to plant.

II. Negative interactions

Member of one population may eat members of the other population, compete for foods, excrete harmful wastes or otherwise interfere with the other population. It includes (i) Competition, (ii) Predation, (iii) Parasitism and (iv) antibiosis.

(i) Competition

It is a condition in which there is a suppression of one organism as the two species struggle for limiting quantities of nutrients O_2 space or other requirements. E. g. Competition between *Fusarium oxysporum* and *Agrobacterium radiobacter*.

(ii) Predation

A predator is free living which catches and kills another species for food. Most of the predatory organisms are animals but there are some plants (carnivorous) also, especially fungi, which feed upon other animals.

Eg. (i) Grazing and browsing by animals on plants.

(ii) Carnivorous plants such as *Nepenthes*, *Darligtoria*, *Drosera* etc. consume insects and other small animals for food.

(iii) Protozoans feeding on bacteria.

(iii.) Parasitism

A parasite is the organism living on or in the body of another organisms and deriving its food more or less permanently from its tissues. A typical parasite lives in its host without killing it, whereas the predator kills its upon which it feeds.

E. g. Species of *Cuscuta* (total stem parasite) grow on other plants on which they depend for nourishment.

Parasitism may occur even with in the species. Hyperparasites which are chiefly fungi growing parasitically on other parasites, (ie) Parasite on a parasite.

Eg. *Cicinnobolus cesatii* is found as hyperparasite on a number of powdery mildew fungi.

(iv) Antibiosis

The phenomenon of the production of antibiotic is called as antibiosis. Antibiotic is an organic substance produced by one organism which in low concentration inhibits the growth of other organism. E. g. Streptomycin, Penicillin. Etc

INTRODUCTION: -

Everything surrounding a living organism like people; place and things constitute its environment which can be either natural or man-made. The word environment has been derived from a French word **'environner'** meaning to encircle or to surround.

The surroundings or settings in which a human being, animal, or plant lives or operates or it is a set of conditions of a living being all the natural forces which provide settings for development and growth as well as danger and damage. In a comprehensive form the environment may be defined as "sum total of living, non-living components; influences and events, surrounding an organism." The environment is not static; rather it's a very dynamic entity. Various factors (biotic & abiotic) are in a flux and keep changing the environment continuously.

TYPES OF ENVIRONMENT: -

On the basis of basic structure, the environment may be divided into

- Physical/abiotic environment
- Biotic environment
- Cultural environment

PHYSICAL/ABIOTIC ENVIRONMENT: - on the basis of physical characteristics and state, abiotic or physical environment is subdivided into:

i. Solid i.e. lithosphere (solid earth)
ii. Liquid i.e. hydrosphere (water component)
iii. Gas i.e. atmosphere (gaseous component)

These environments can be termed as lithospheric, hydrosspheic, atmospheric environment which can be further broken into smaller units based on different spatial scales like mountain environment, plateau, plain, lake, river maritime, glacier, desert environment etc. The physical environment may also be viewed in terms of climatic conditions providing certain suits of habitat for biological communities like tropical, temperate and polar environment etc.

BIOTIC ENVIRONMENT-: biotic environment consists of flora and fauna including man as an important factor. Thus the biotic environment may be divided into:

iv. Floral environment
v. Faunal environment

COMPONENTS OF ENVIRONMENT: -

The basic components of the environment are atmosphere or the air, lithosphere or the rocks and soil, hydrosphere or the water, and the living component of the environment or the biosphere.

ATMOSPHERE: -

- the thick gaseous layer surrounding the earth.
- It spreads up to 300 km. above the earth's surface.
- Apart from gases there are water vapor, industrial gases, dust and smoke particles in suspended

state, microorganism etc.

LITHOSPHERE: -

The word lithosphere originated from a Greek word mean "rocky" + "sphere” i.e. the solid outmost shield of the rocky planet. The Earth is an oblate spheroid. It is composed of a number of different layers. These layers are:

- The Core which is around 7000 kilometers in diameter (3500 kilometers in radius) and is situated at the Earth's center.
- The Mantle which environs the core and has a thickness of 2900 kilometers.
- The Crust floats on top of the mantle and is composed of basalt rich oceanic crust and granitic rich continental crust.

HYDROSPHERE: -

- The hydrosphere includes all water on or near earth surface and includes oceans, lakes, rivers, wetlands, icecaps, clouds, soils, rock layers beneath surface etc.
- water exist in all three states: solid (ice), liquid (water), and gas (water vapor)
- 71%of planet surface is covered with water
- Freshwater- 2.53%
- Freshwater in glaciers-1.74%
- Water as water vapour in atmosphere-12,900 km^3
- living organism contain- 1100 km^3

Since the environment includes both physical and biological concept, it embraces both the abiotic (non-living) and biotic (living) components of planet earth. Thus, on account of basic structure the components of environment may be classified into two basic types:

Figure 1: Components of Environment

ABIOTIC COMPONENTS (NON-LIVING): - these are the most important determining factor of where and how well an organism exists in the environment. Although these factors interact with each other, one single factor can limit the range of an organism thus acting as the limiting factor. These factors can be categorised into following groups:

PHYSICAL FACTORS: - the major components are temperature, Water (Rainfall), Light (Energy), Soil, Atmospheric pressure.

TEMPERATURE: - Temperature is the most ecologically germane environmental factor. It's a very well-known and an established fact that the average temperature on land varies seasonally, decreasing progressively from the equator towards the poles and from plains to the top of mountains ranging from sub-zero levels to >50˚C in polar areas/high altitudes and tropical deserts in summer respectively. A few organisms can tolerate and thrive in a wide range of temperatures without having effect on their internal environment (they are called eurythermal), but, a vast majority of them operate within a narrow range of temperatures (such organisms are called stenothermal).

WATER (RAINFALL): - Water is another most important factor influencing the life of organisms. In fact, genesis of life on earth is attributed to water without which life is unsustainable. Its availability is too scarce in deserts. Due to this scarcity only special adaptations by plants and animals of this region make it possible to survive there in such an unusual living conditions. The productivity and distribution of plants is also profoundly dependent on water.

LIGHT (ENERGY): - One can quickly and easily understand the importance of light/energy for living organisms, particularly autotrophs since they produce/manufacture food through photosynthesis, a specialised process which is only possible with the availability of sunlight as a source of energy.

SOIL: - The nature and properties of soil in various places vary to a great extent depending upon the climate which includes temperature and humidity, the weathering process, whether soil is transported or sedimentary and how soil development occurred. Various physical characteristics of the soil such as soil composition, grain size and aggregation determine the percolation and water holding capacity of the soil.

INORGANIC AND ORGANIC SUBSTANCES: - Water, Oxygen, Carbon, Nitrogen, Sulphur, Nitrates, Phosphates and ions of various metals etc. are inorganic substances essential for organisms to survive while proteins, Carbohydrates, Lipids etc. are essential Organic substances:

BIOTIC COMPONENTS (LIVING): - It consists of the living parts of the environment, including the association of a lot of interrelated populations that belong to different species inhabiting a common environment. The populations are those of the animal community, the plant community and the microbial community.

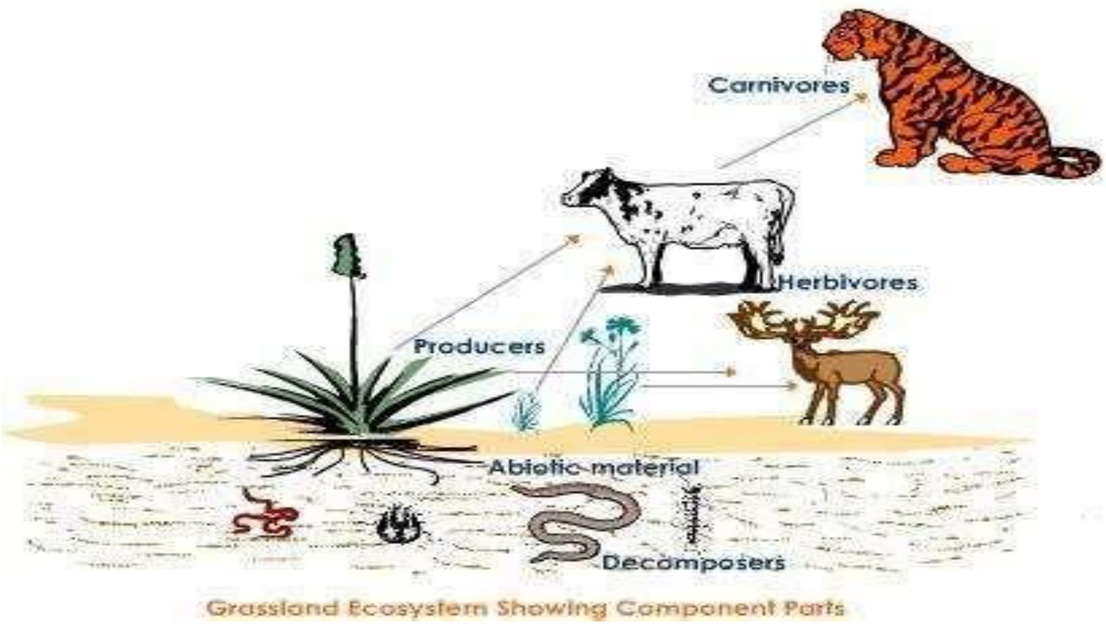

Figure 1: Components of biotic community.

The biotic community is divided into:

a. Autotrophs,
b. Saprotrophs, and
c. Heterotrophs

AUTOTROPHS (derive from Greek word: auto - self, trophos - feeder) are called producers, transducers or convertors, as well. Those are photosynthetic plants, normally chlorophyll bearing, which synthesize a high-energy complex organic compound (food) from the inorganic raw materials utilizing the aid of the sun, and this process is called photosynthesis. Autotrophs form the core of all biotic systems. In terrestrial ecosystems, autotrophs are usually rooted plants. In the aquatic ecosystems, the floating plants referred to as phytoplankton and the shallow water rooted plants – macrophytes - are the main producers.

HETEROTROPHS (from Greek: heteros - other; trophs - feeder) are the consumers, normally animals that feed on the other organisms. Consumers are also referred to as phagotrophs (phago - to swallow or ingest) while macroconsumers are normally herbivores and carnivores. Herbivores are called First order or primary consumers, for they feed directly on green plants. For example, Terrestrial ecosystem consumers are cattle, deer, grass hopper, rabbit, etc. Aquatic ecosystem consumers are protozoans, crustaceans, etc.

Carnivores are animals that prey or feed on other animals. Second order consumers or Primary carnivores include those animals that feed on herbivorous animals. For example, fox, frog, smaller fishes, predatory birds, snakes, etc.

Third order consumers or Secondary carnivores are the animals that feed on primary carnivores. For example, wolf, owl, peacock, etc. Some larger carnivores prey on Secondary carnivores. Quaternary consumers or Tertiary carnivores include those animals which feed upon secondary carnivores. For example, the lion, the tiger, etc. Those are not eated by any other animal. The larger carnivores which cannot be preyed on further are also called the top carnivores.

SAPROTROPHS (from Greek again: sapros - rotten; trophos - feeder) are called the reducers or decomposers or osmotrophs. They break the complex organic compounds in dead matter down (dead plants and animals). Decomposers don't ingest the food. Instead they secrete a digestive enzyme into the dead, decaying plant or animal remains and digest this organic material. The enzymes act on the complex organic compounds in the dead matter. Decomposers absorb a bit of the decomposition products to provide themselves with nourishment. The remaining substance is added as minerals in the process of mineralisation to the substratum. Released minerals are utilised or reused as nutrients by plants - the producers.

COMMUNITY ECOLOGY

A naturally occurring group of different plant and animal populations living in common environment constitute a biotic community. Assemblage of plant populations in a biotic community is called plant community and that of animal populations is called animal community. The study of an organisms living together in an interrelated manner in a given environment is termed as community ecology or synecology.

Features of a community:

1. A community is a highly complex structure, dominant species are tree and shrubs.
2. The number of species in a community is determined by variation of environmental conditions.
3. If the conditions are adverse, the number of species present in a community is also less than average.
4. Closely related species normally do not occur at the same place, at same time, or in closely related niches.
5. Community vary in size and composition, smaller is called micro community e.g. water in a pitcher.

CLASSIFICATION OF COMMUNITIES

1. Terrestrial (land)
2. Aquatic (water)

These two basic types of community contain smaller units known as Biomes.

•Terrestrial Biomes: tundra, grassland, desert, taiga, temperate forest, tropical forest.

• Aquatic Biomes: marine, freshwater.

Autotrophic communities require only the energy from the sun to drive the process of photosynthesis, such as forests and grasslands.

Heterotrophic communities, such as organisms that inhabit a fallen log, depend on the autotrophic community for their energy source.

All communities have certain characteristics that define their biological and physical structure, but these characteristics vary in both space and time.

CHARACTERISTICS OF COMMUNITY ECOLOGY

Some of the major characteristics of community ecology are as follows:

1. Species Diversity
2. Growth From and structure
3. Dominance
4. Self reliance
5. Relative abundance
6. Trophic structure.

Community ecology deals with the group of various kinds of population in the areas. A group of several species (plants/ animals) living together with mutual tolerance in a natural area is called as a community. A forest, a pond and a desert are natural communities. A community has its own structure, development history and behaviours.

The community has the following characteristics:

(a) Species Diversity:

Each community consists of different organisms like plants, animals, microbes etc. They differ taxonomically from each other. This species diversity may be regional or local.

(b) Growth From and structure:

Community can be analysed in terms of major growth forms like trees, shrubs, herbs etc. In each growth from as in trees, there may be different kinds of plants as-broad leave trees, evergreen trees etc. These different growth forms determine the structural pattern of a community.

(c) Dominance:

All species are not equally important in each community. The nature of the community is determined by a few species in a community. These limited species have control and dominating influence in the community.

(d) Self reliance:

Each community has a group of autotrophic plants as well as heterotrophic animals. The autotrophic plants are self dependent.

(e) Relative abundance:

Different populations in a community exist in relative proportions and this idea is called as relative abundance.

(f) Trophic structure:

Each community has a trophic structure that determines the flow of energy and material from plants to herbivores to carnivores.

Characteristics of Communities:

Communities, like populations, are characterised by a number of unique properties which are referred to as community structure and community function. Community structure comprises of species richness (types of species and their relative abundances) physical characteristics of the vegetation and the trophic relationships among the interacting populations in the community.

The characteristic features of a community are:

A. Species composition:

A community is a heterogeneous assemblage of plants, animals and microbes. In ecosystems, virtually every organisms of a community, including the most insignificant microbes, plays some role or the other in determining its nature. The species in a community may be closely or distantly related but they are interdependent and are interacting with each other in several ways.

B. Species dominance:

All the species of a community are not equally important. There are a few overtopping or dominant species who, by their bulk and growth, modify the habitat. They also control the growth of other species of the community, thus forming a sort of nucleus in the community.

Some communities have a single dominant species and are thus named after that species, such as sphagnum bog community, deciduous forest community etc.

1. Keystone Species:

There are species upon whom several species depend and whose removal would lead to a collapse of the structure and ultimate disappearance of these other species. Such species are referred to as keystone species, the term coined by Paine in 1966. These species may exert their keystone role in several ways.

2. Direct-Indirect Interactions:

In order to understand the structure of the community, one has to determine which possible interactions are the most important. When direct physical contact of one species with another is involved the interaction is said to be a direct interaction as in predation, herbivory and parasitism.

3. Chemical Interactions among Species:

In a number of cases, species relationships are based on chemical interactions. The study of the production and uptake or reception by organisms of chemical compounds having effects on the organisms is termed chemical ecology.

PRODUCTIVITY

Productivity in ecosystem can be defined as the rate at which the biomass increases per unit area. It can be measured in units of biomass per unit volume per unit area, *i.e.*, gm–2 yr–1 or (kcal m–2) yr^{-1}. **Biomass** can be defined as dry matter or dry mass. Productivity often depends on the ecosystem. Each ecosystem has a different number of producers, consumers, and decomposers, which affects productivity greatly. The ecological productivity can usually be characterized as a pyramid structure that depicts the food web. Moreover, primary and secondary productivity is as important as ecological productivity.

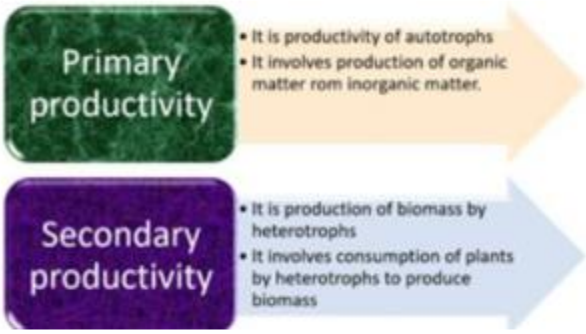

Figure 1: Types of productivity

TYPES OF PRODUCTIVITY

Primary Productivity in Ecosystem

1. It is carried out by autotrophs or producers. Primary productivity can be defined as the amount of solar energy converted to chemical energy by an ecosystem's producers for a given area during a certain time period. Producers produce biomass by performing photosynthesis. Some primary producers can be chemosynthetic as well, i.e., they produce biomass by chemosynthesis. E.g., Purple sulfur bacteria.

Primary productivity can be divided into two types as below:

Gross primary productivity (GPP): The total solar energy used to produce biomass by the process of photosynthesis is referred to as gross primary productivity (GPP). It is the rate of production of organic matter. Some amount of GPP is utilized by the plant itself, and a very little amount is transferred to the consumers. Most of the GPP is lost due to plants' internal metabolism or cellular respiration or growth and repair mechanism. The lost GPP is referred to as respiratory loss (R).

Net primary productivity (NPP): Net primary productivity is the amount of biomass available for the consumers or heterotrophs after respiratory loss. This biomass is stored in the plants. Net primary production forms the base of ecological food chains and is heavily manipulated by humans in the production of food, fiber, wood, and increasingly biofuels. This can be described as: **NPP = GPP – R**

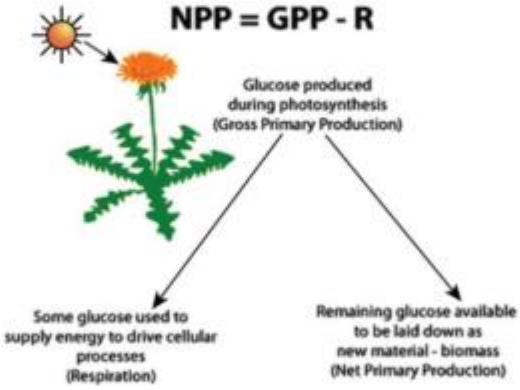

Figure 2: Depiction of GPP, NPP, and R

The tropical forest has the highest primary productivity in terrestrial regions, while the desert shows the least primary productivity. The primary productivity of a natural ecosystem largely depends upon the amount of solar energy; there is a positive correlation between primary productivity and solar radiation. Since solar radiation received at the Earth's surface decreases as we move from the equator towards the poles, primary productivity also decreases remarkably towards the poles.

Secondary Productivity in Ecosystem

Secondary productivity can be defined as the rate of biomass production by consumers or herbivores. The organism that cannot produce its own food and can obtain energy from biomass produced due to primary productivity. Now, the thing to be noticed here is unlike

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primary productivity, at the level of secondary productivity, different trophic levels exist like herbivores, carnivores, omnivores, etc. Each trophic level consumes biomass but assimilates only 10% of it into energy, and the rest of the undigested biomass is released in the form of fecal waste and left to be used by other trophic levels or decomposers. The assimilated energy is used for various metabolic processes, growth, and reproduction, etc. Entire secondary productivity represents energy flow through trophic levels. Secondary productivity is basically the amount of energy stored in the tissues of consumers of each trophic level.

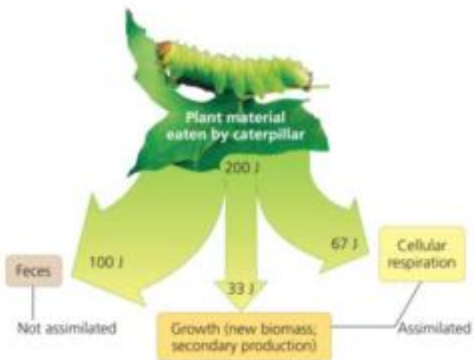


Figure 3: Secondary Productivity and Energy Flow

In terrestrial ecosystems, productivity is highest in Swamps, marshes, tropical rain forests (most productive), while lowest in the desert. In contrast, in aquatic ecosystems, productivity is highest in the Estuaries, lowest in the open ocean.

ENERGY FLOW IN ECOSYSTEMS

Food Chains

Your understanding of biology may help you understand this section and next section more. Around you exist, several food chains. Did I hear you say really? Yes it does, even sometimes as close as in your bedroom.

Imagine yourself outdoors in a garden, perching on the flower plant is a butterfly taking nectar from the plant. On satisfaction, the butterfly left flower to land on a nearby wall, unknown to the butterfly, an hungry lizard was lying tired nearby, what happen next is that the lizard on sighting the butterfly turned it to a meal. After the meal, the lizard decided to sun itself. It however ended being swallowed by another reptile - a snake (python).

What you observed in the depiction above is what is called a food chain. It is presented below in a simplified diagram (Fig. 3.1)

Flow Plant (Nectar) → Butterfly → Lizard → Snake

A simplified diagram of food chain

Now let us examine the following definitions:" Food chain is a structured feeding hierarchy whereby energy in the form of food is passed from an organism in a lower tropic level (any of a series of distinct feeding or nourishment levels in a food chain) to one in a higher level. (Collins Dictionary of Environment Science)

The first strophic level (T_1) comprises of the primary producers (plants); T_2 the primary consumers (herbivores) or plant eaters); T_3, secondary consumers (carnivores or meat eaters); and T_4, Tertiary consumer (next eaters at the top of the food chain.

From Fig. 3.1, we can categorize as follows:

Flower Plant (Nectar)	-	T_1Butterfly	-	T_2	
Lizard	-	T_3			

Snake (Python) - T_4

A simpler definition of a food chain is a series of organisms each eating or decomposing the preceding one.

It is important for you to know that the food chain concept is useful for tracing chemical recycling and energy flow in an ecosystem. (You will discover these next two sections ahead).

Food Web

Since you now understand the food chain. What then is a food web? Food web is the same as a food chain you want so say? Certainly you are right. It is just that a food web is more complex than a food chain. In a food web you rarely see what you have in a simple food chain, shown figure 3.1 above. However, what exist in a real term is frequently arranged as complex interconnected food chain or network. It is this interconnected food chain or network that is referred to as the food web.

This means that more organisms in an ecosystem are involved in a food web (Figure 3.2)

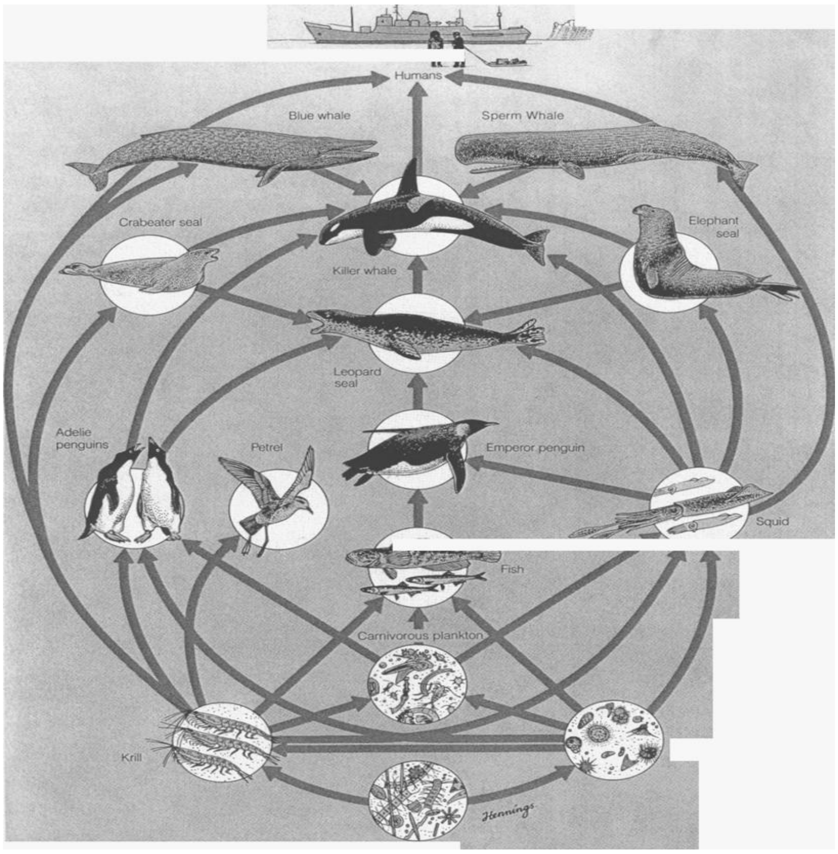


Figure 3.2 greatly simplified food web in the Antarctic. There are many more participants, including and array of decomposer organisms.
Source: Miller G.T. (1991.73)

Energy Flow Pyramid

From your elementary knowledge of physics, energy is the capacity of a body or system to do work. With the understanding of energy, we can say that what we want to know in this section is the transfer of energy within an ecosystem. In order to understand this section, organisms are grouped by function according to their tropic level- you should remember that tropic level is the level at which they gain nourishment. Each successive tropic levels organism depends upon those of the next lowest for energy requirements (food). (Figure 3.3).

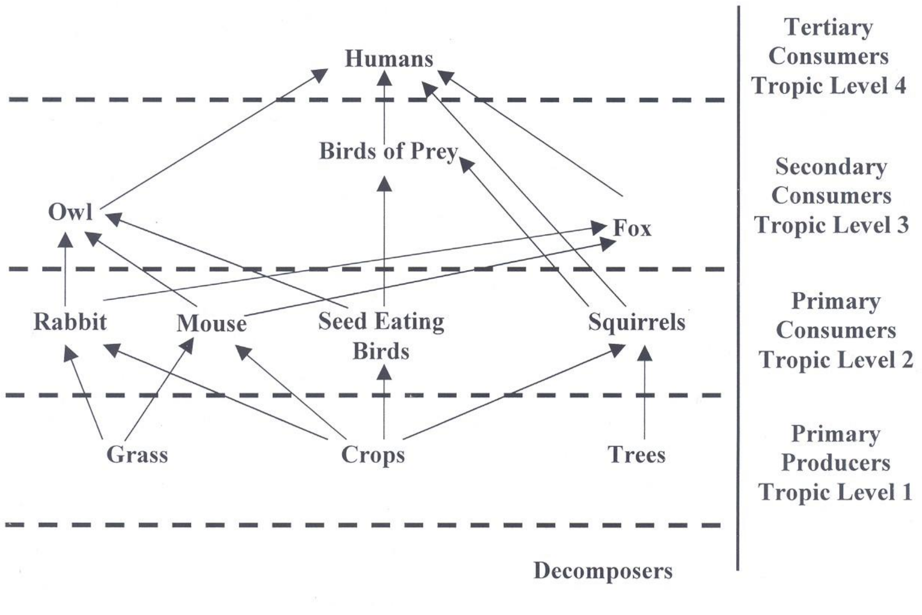


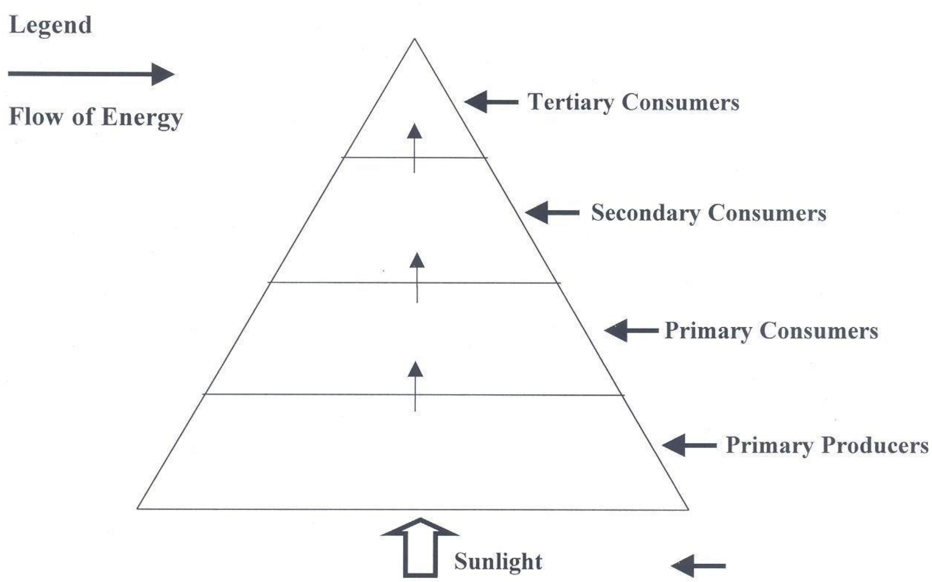
Fig. 3.3: Tropic Level: The arrangement of species in a food chain into feeding levels. The arrows show main directions of movement of energy and materials.

Adapted from Collins Dictionary of Environmental Science.

From the diagram, you will see that the first tropic level, primary producers in virtually every case convert sunlight into chemical energy.

You must have noticed that tropic level I is almost always photosynthetic plant. Transfer of energy continues level by level from the first tropic level. One basic point to note is that at each transfer from one tropic level to another in a food chain or web, work done is reduced.

This is so because low-quality heat is given to the environment, and the availability of high-quality energy to organisms at the next tropic level is reduced. In essence, within an ecosystem there is likely to be a pyramid shaped patter of tropic levels for organisms to consume others withgreater mass and number of



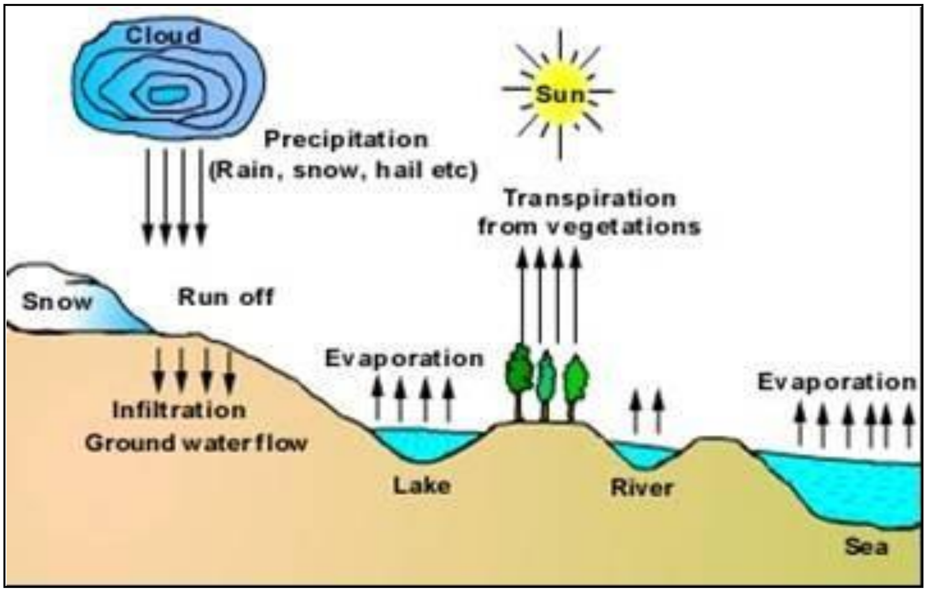
organisms at lower levels.

Figure 3.4: Energy Pyramid: The arrows shows the transfer of energy between each tropic level.

According to Miller (1991:72) the energy - flow pyramid explains why alarger population of people can be supported if people shorten the food chain by eating grains directly (for example, rice humans) rather than eating animals that feed on grains (grain steer human). Adapted barrow (1993)

ENERGY FLOW AND BIOGEOCHEMICAL CYCLES

Biogeochemical cycles describe the circulation of matter, particularly plant and animal nutrients, through ecosystems. These cycles are ultimately powered by solar energy, fine-tuned and directed by energy expended by organisms. In a sense, the solar-energy-powered hydrologic cycle acts as an endless conveyer belt to move materials essential for life through ecosystems.



Most biogeochemical cycles can be described as elemental cycles involving nutrient elements such as carbon, oxygen, nitrogen, sulfur and phosphorus. Many are gaseous cycles in which the element in question spends part of the cycle in the atmosphere – O_2 for oxygen, N_2 for nitrogen, CO_2 for carbon. Others, notably the phosphorus cycle, do not have a gaseous component and are called sedimentary cycles. All sedimentary cycles involve salt solutions or soil solutions that contain dissolved substances leached from weathered minerals that may be deposited as mineral formations or they may be taken up by organisms as nutrients. The sulfur cycle, which may have H_2S or SO_2 in the gaseous phase or minerals ($CaSO_4$ $2H_2O$) in the solid phase, is a combination of gaseous and sedimentary cycles.

CARBON CYCLE

Carbon, the basic building block of life molecules, is circulated through the carbon cycle. This cycle shows that carbon may be present as gaseous atmospheric CO_2, dissolved in groundwater as HCO_3 or molecular CO_2 (aq), in underlying rock strata as limestone ($CaCO_3$), and as organic matter, represented in a simplified manner as (CH_2O). Photosynthesis fixes inorganic carbon as biological carbon, which is a constituent of all life molecules.

An important aspect of the carbon cycle is that it is the cycle by which energy is transferred to biological systems. Organic or biological carbon, (CH_2O), is an energy-rich molecule that can react biochemically with molecular oxygen, O_2, to regenerate carbon dioxide and produce energy. This can occur in an organism as shown by the "decay" reaction or it may take place as combustion, such as when wood is burned.

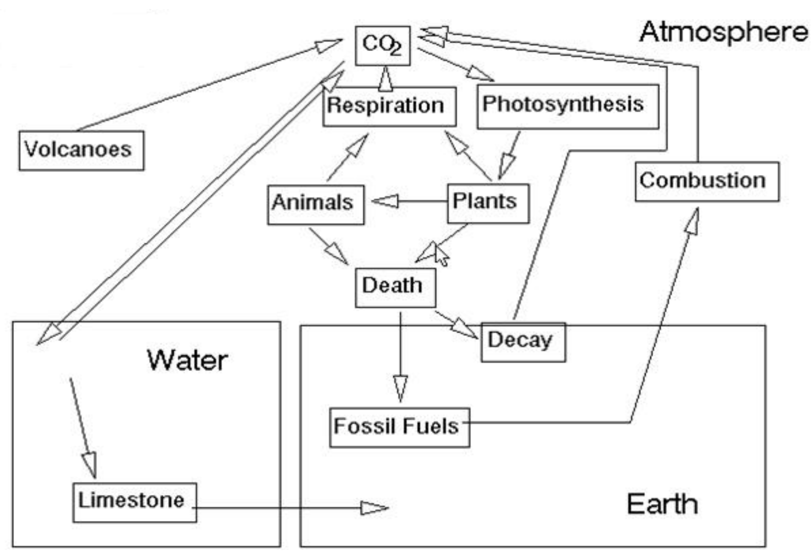


Figure 2: Carbon cycle

OXYGEN CYCLE

The oxygen cycle involves the interchange of oxygen between the elemental form of gaseous O_2 in the atmosphere and chemically bound O in CO_2, H_2O, and organic matter. Elemental oxygen becomes chemically bound by various energy-yielding processes, particularly combustion and metabolic processes in organisms. It is released during photosynthesis.

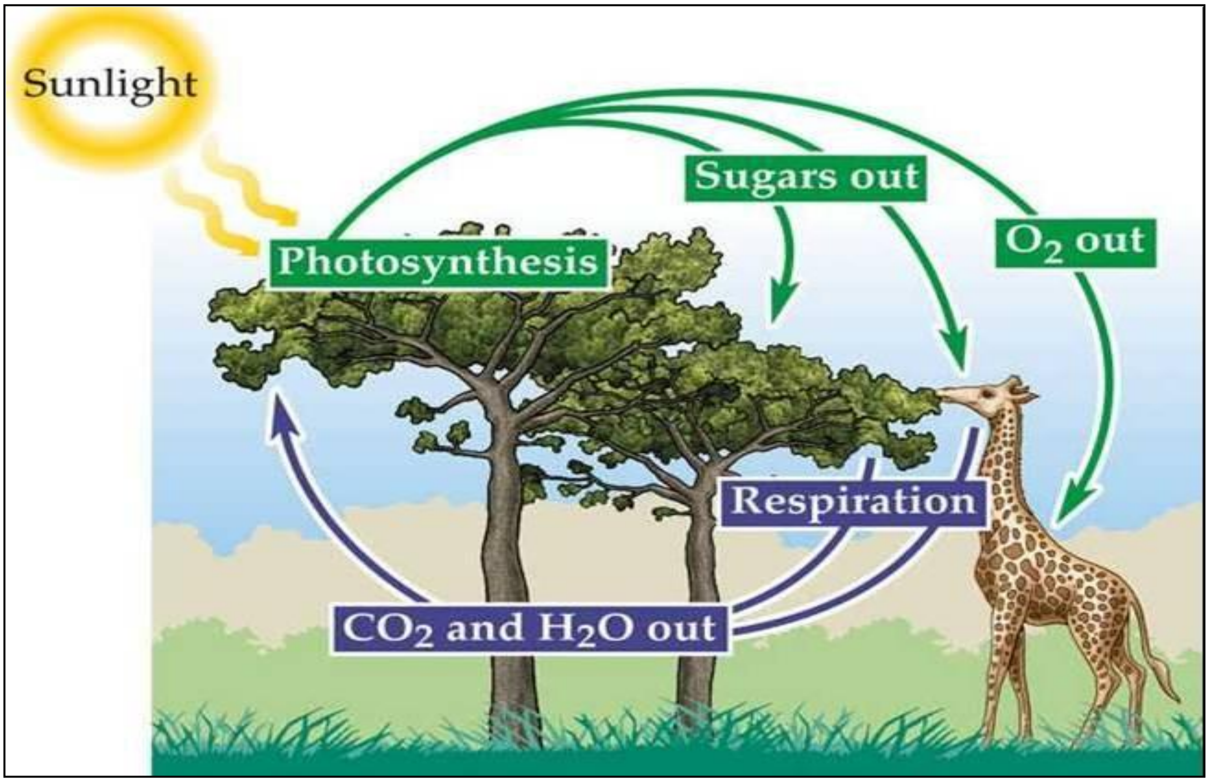


Figure 3: Oxygen cycle

Nitrogen Cycle

Nitrogen, though constituting much less of biomass than carbon or oxygen, is an essential constituent of proteins. The atmosphere is 78% by volume elemental nitrogen, N_2 and constitutes an inexhaustible reservoir of this essential element. The N_2 molecule is very stable so that breaking it down to atoms that can be incorporated in inorganic and organic chemical forms of nitrogen is the limiting step in the nitrogen cycle. This does occur by highly energetic processes in lightning discharges such that nitrogen becomes chemically combined with hydrogen or oxygen as ammonia or nitrogen oxides. Elemental nitrogen is also incorporated into chemically bound forms or fixed by biochemical processes mediated by microorganisms. The biological nitrogen is returned to the inorganic form duringthe decay of biomass by a process called mineralization.

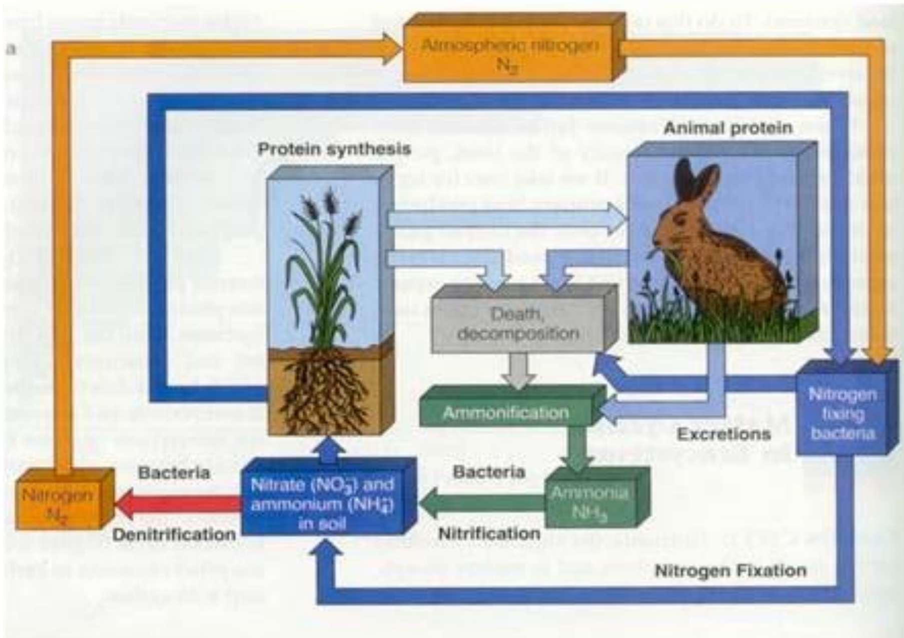


Figure 3: Nitrogen Cycle

PHOSPHORUS CYCLE

The phosphorus cycle is crucial because phosphorus is usually the limiting nutrient in ecosystems. There are no common stable gaseous forms of phosphorus, so the phosphorus cycle is strictly sedimentary. In the geosphere phosphorus is held largely in poorly soluble minerals, such as hydroxyapatite, a calcium salt. Soluble phosphorus from these minerals and other sources, such as fertilizers, is taken up by plants and incorporated into the nucleic acids of biomass. Mineralization of biomass by microbial decay returns phosphorus to the salt solution from which it may precipitate as mineral matter.

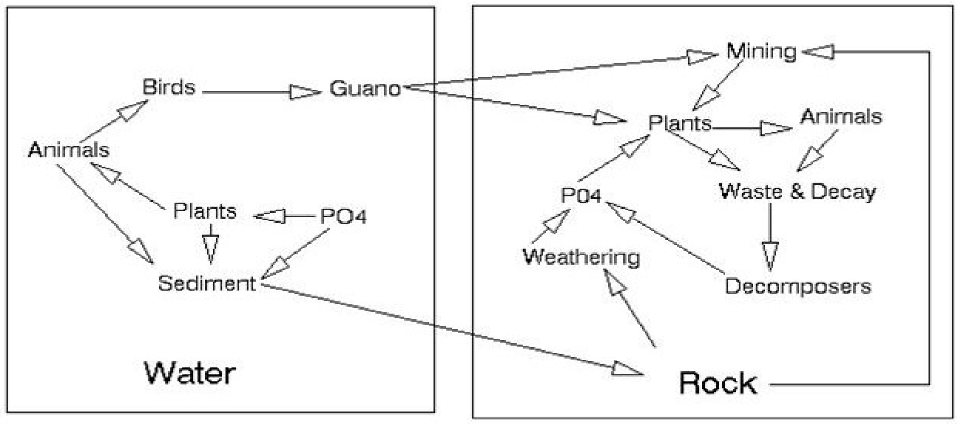


Figure 4: Phosphorus cycle

SULFUR CYCLE

The sulfur cycle is relatively complex. It involves several gaseous species, poorly soluble minerals, and several species in solution. It is involved with the oxygen cycle in that sulfur combines with oxygen to form gaseous sulfur di oxide (SO_2) an atmospheric pollutant, and soluble sulfate ion, (SO_4^{2-}). Among the significant species involved in the sulfur cycle are gaseous hydrogen sulfide, H_2S; mineral sulfides, such as PbS; sulfuric acid, H_2SO_4, the main constituent of acid rain; and biologically bound sulfur in sulfur-containing proteins.

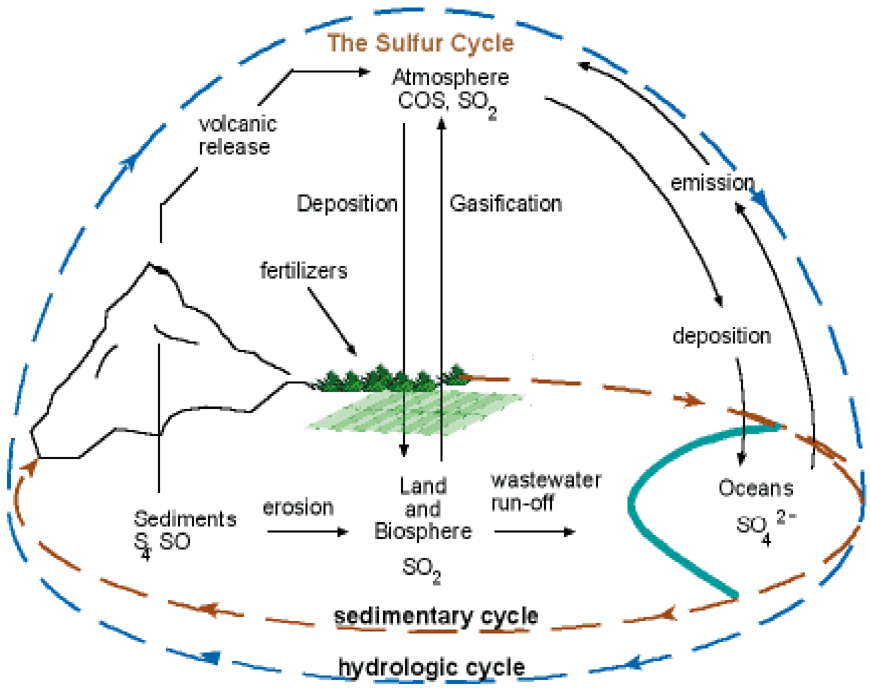


Figure 5: Sulfur cycle

ENERGY AND CYCLES OF ENERGY

Biogeochemical cycles and virtually all other processes on Earth are drive by energy from the sun. The sun acts as a blackbody radiator with an effective surface temperature of 5780 K (Celsius degrees above absolute zero). It transmits energy to earth as electromagnetic radiation. The maximum energy flux of the incoming solar energy is at a wavelength of about 500 nanometers, which is in the visible region of the spectrum. A 1 square meter area perpendicular to the line of solar flux at the top of the atmosphere receives energy at a rate of 1,340 watts, sufficient, for example, to power an electric iron. This is called solar flux.

Energy in natural systems is transferred by heat, which is the form of energy that flows between two bodies as a result of their difference in temperature, or by work, which is transfer of energy that does not depend upon a temperature difference, as governed by the laws of thermodynamics. The first law of thermodynamics states that, although energy may be transferred or transformed, it is conserved and is not lost. Chemical energy in the food ingested by organisms is converted by metabolic processes to work or heat that can be utilized by the organisms, but there is no net gain or loss of energy overall. The second law of thermodynamics describes the tendency toward disorder in natural systems. It demonstrates that each time energy is transformed; some is lost in the sense that it cannot be utilized forwork, so only a fraction of the energy that organisms derive from metabolizing food can be converted towork; the rest is dissipated as heat.

ENERGY FLOW AND PHOTOSYNTHESIS

Whereas materials are recycled through ecosystems, the flow of useful energy may be viewed as essentially a one-way process. Incoming solar energy can be regarded as high-grade energy because it can cause useful reactions to occur, the most important of which in living systems is photosynthesis. Solar energy captured by green plants energizes chlorophyll, which in turn powers metabolic processes that produce carbohydrates from water and carbon dioxide. These carbohydrates represent stored chemical energy that can be converted to heat and work by metabolic reactions with oxygen in organisms. Ultimately, most of the energy is converted to low-grade heat, which is eventually re- radiated away from Earth by infrared radiation.

SUCCESSION

The Environment is always kept on changing over a period of time due to:

- variations in climatic and physiographic factors
- the activities of the species of the communities themselves.

These influences bring about marked changes in the dominants of the existing community, which is thus sooner or later replaced by another community at the same place. This process continues and successive communities develop one after another over the same area until the terminal final community again becomes more or less stable for a period of time. It occurs in a relatively definite sequence. This orderly change in communities is referred as succession.

Succession is an orderly process of community development that involves changes in species structure and community processes with time and it is reasonably directional and therefore predictable. Succession is community controlled even though the physical environment determines the pattern.

CAUSES OF SUCCESSION

Succession is a series of complex processes, caused by

(I) Initial/initiating cause: Both climatic as well as biotic.

(II) Ecesis/continuing process ecesis, aggregation, competition reaction etc.

(III) Stabilizing cause: Cause the stabilization of the community. Climate is the chief cause of stabilization and other factors are of secondary value.

TYPES OF SUCCESSION

- Primary succession: Starts from the primitive substratum where there was no previously any sort of living matter. The first group of organisms establishing there are known as the pioneers, primary community/primary colonizers. Very slow is the series of community changes that takes place in disturbed areas that have not been totally stripped their soil and vegetation.
- Secondary succession: Starts from previously built up substrata with already existing living matter. Action of and external force, as a sudden change in climatic factors, biotic intervention, fire etc, causes the existing community to disappear. Thus area becomes devoid of living matter but its substratum, instead of primitive is built up. Such successions are comparatively more rapid.
- Autogenic succession: Community - result of its reaction with the environment, modified its own environment and thus causing its own replacement by new communities. This course of succession

is autogenic succession.

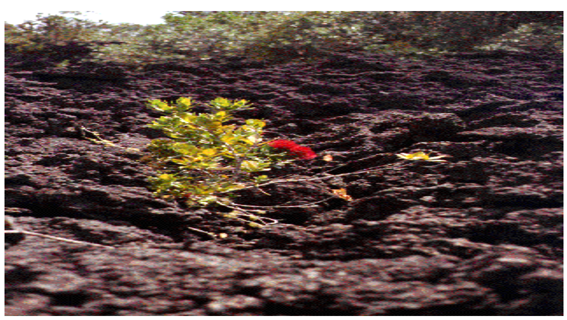
- Allogenic succession: Replacement of the existing community is caused largely by any other external condition and not by the existing organisms.
- Autotrophic succession: Characterized by early and continued dominance of autotrophic organisms like green plants. Gradual increase in organic matter content supported by energy flow.
- Heterotrophic succession: Characterized by early dominance of heterotrophs, such as bacteria, actinomyces, fungi and animals. There is a progressive decline in the energy content.

General Process of succession

(i) Nudation: Development of barren area without any form of life. Cause of nudation: It may be (a) Topographic soil erosion by wind (b) Climatic - storm, frost etc. (c) Biotic - man, disease and epidemics.

(ii) Invasion: Successful establishment of a species in a barren area. This species actually reaches this new site from any other area by (i) Migration, (ii) Ecesis and (iii) Aggregation.

Slow soil development by weathering, activities of tolerant species Pioneer Species



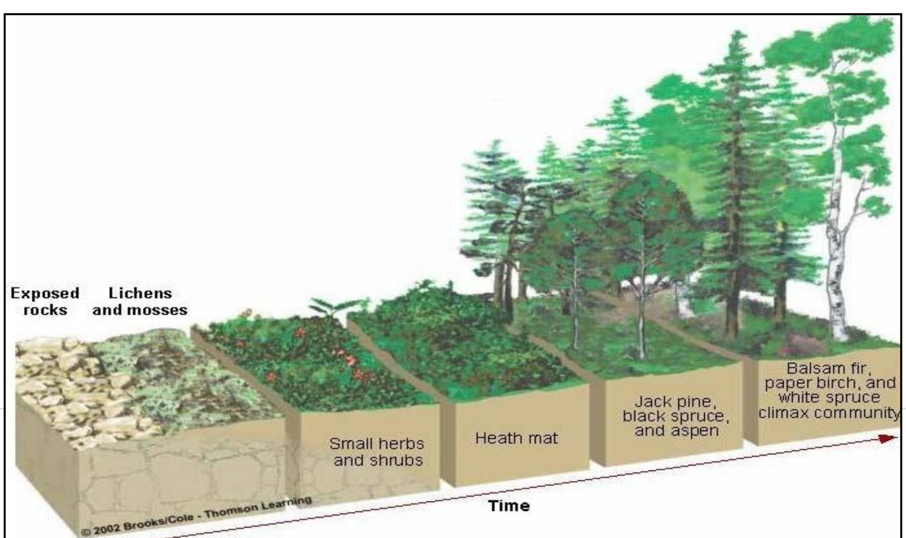
Retrogressive succession:

Continuous biotic influences have some degenerating influence on the process. Due to destructive effects of organisms, the development of disturbed communities does not occur. Process of succession, instead of progressive, it becomes retrogressive. (Eg.) Forest may change to shrubby or grassland community.

Deflected succession:

Sometimes due to changes in local conditions as soil character or microclimate the process of succession becomes deflected in a different direction than that presumed under climatic conditions of the area. Thus the climax communities are likely to be different from the presumed climatic climax community.

Gradual changeover to less tolerant species over long periods of time



Primary **Succession**

Outcome of Succession

The following are the outcome or results of Succession:

1. Replacement by complex organisms: Simpler organisms which start the succession are usually replaced by more complex ones in an evolutionary trend sequence.

2. Changes in the physical environment: Changes in the physical environment is attained from the structural changes of the species and the activities in the community.

3) Fast replacement: As some species make conditions favourable for others they in turn create unfavourable conditions for themselves, thereby increasing the process of replacement.

4) Attainment of equilibrium point: Equilibrium point is attained through colonization of the abandoned farmland by a wide variety of organisms that are just the same with a neighbouring habitat.

(5) Climax community form the final stage: The final outcome of succession is the climax or stable community.

POPULATION DYNAMICS

A **population** describes a group of individuals of the same species occupying a specific area at a specific time. **Population dynamics** is a study of the variation in the population of a particular species at a location over a given period of time. The population of each species has a unique physical distribution which changes over time and space based on how successful the species has been in thriving in that particular environment.

Population dynamics helps to answer how, when and why the changes occur. The study of population dynamics in Biology is a very effective way of evaluating the impact of the physical environment on the species. The change in the density of the population of a particular species in one location is dependent on the births, deaths, immigration, and migration of the species. The values of these four factors birth (natality), deaths (mortality), immigration (influx) and emigration (outflux) help in determining whether the population in a given area will increase or decrease. A population whose density remains stable is said to be in equilibrium.

The population parameters, or characteristics, describe how the population density changes over time. The ways in which population densities fluctuate— increasing, decreasing, or both over time—is the subject of population dynamics.

Population dynamics as a branch of study not only deals with the study of the composition of the population but also includes the study of the various environmental processes that influence the change in the density.

Some of the environmental factors include the availability of resources, climate, possible predators, availability of reproductive conditions and possible pathogens.

- The availability of abundant resources helps in the growth of a population which not only helps to sustain a greater number of individuals of the same species but also promotes immigration. However, this increase in population will be followed by a decrease as the resources get limited and subsequently dry out. This results in starvation and mortality accompanied by emigration.
- Climatic variations also lead to significant variation in the population of a particular species. This is quite apparent in many bird species that have moved to the Endangered category due to the global changes in the weather conditions. While warmer climates have resulted in the increase of population density of certain species it has led to the drastic drop in many cold weather species.
- The presence or absence of predators in an ecological system can greatly affect the population of a species. The presence of a predator helps in a great way to maintain the ecological balance in the location. The ratio of the predator to prey has to be such that neither is forced to extinction. Too many predators in an area will lead to a shortage of prey which will subsequently lead to the

starvation of the predators and their deaths. A large number of preys would mean greater use of the resources such that neither the prey nor the predator can survive.

- The survival of a species is greatly dependent on the birth rate. If the conditions are not conducive for the reproduction and nurturing of the off-springs the population will see a steady decline as the age of the population keeps growing without the addition of younger individuals.
- A very versatile and abundant environment may not always be supportive of the survival of a species. This may be due to the presence of a pathogen which can infect and raise the death rate or mortality in a species. A study of the population dynamics caused due to the presence of a pathogen can give an understanding to what extent it can affect the population in a certain location.

There are various other environmental factors that can influence which have been incorporated into the study of the Population Models.

Methods used to measure the population Density

Various quantitative methods are used by biologists to determine the population density in an area.

1. **Total count or Complete count method**: it is a simple method used to count all the individuals in an area. It is used in determining the population density of humans in an area. However, it is not a sound way to determine the density of animal species or plant species in a particular area. In such cases estimates of the population is obtained by alternative methods.
2. **Quadrat method**: The Quadrat method is effective in measuring the population densities of a species that is more or less uniformly distributed over the area of study. In the Quadrat method, all the individuals of a species are counted in a smaller area called as a subplot and the number derived is used to determine the total number of individuals in the entire habitat or area of study. This, of course, does not yield the exact population but gives an estimate of the population density based on the consideration that the population is evenly spread across the area. This method is also known as the **Incomplete count** method. It is commonly used in the study of plant species and other species that are not very mobile.
3. **Capture - recapture** method: This is used for more mobile species. This method is popularly used to estimate populations of game and non-game animals and some fishes. First used by Petersen in 1896 to the study the European Plaice in the Baltic Sea and later used by Lincoln in 1930 to estimate the population of ducks. It is often called as the **Lincoln-Petersen index** which involves the capture and marking of a number of a number of animals and releasing them back to the population and then determining the ration of the marked to unmarked animals in the second capture of animals

$$P=MC/R$$

Where P is the population estimate

M is the number of marked animals in the first capture

C is the number of animals in the second capture

R is the number of marked animals found in the second capture.

4. **Indirect count** method. It may not be always possible to obtain the visual or auditory data to estimate the population; in this case, the indirect method is implemented to determine the population density. Here indirect signs of the presence of an animal are used as reference indices for relative abundance of the species. For example in the area of study, the deer faecal pellets are removed and then after a specific interval of time all the new piles of faecal pellets are counted to help determine the number of deer in that area. Other common indices used are dens, nests, birds singing.

Population Types

There are basically two types of the population; **structured** and **unstructured**. In the **structured population**, all the individuals in the population have a unique way of reacting to the environment. They vary in the way they are susceptible to the general ecological pressures. While some may be more susceptible to reproduce more in a given condition, others might be susceptible to mortality. On the other hand in the **unstructured population** type, all the individuals in the species more or less react in the same way. They may have the same growth rate and lifespan with similar reproductive capacities.

The birthrate of a population describes the number of new individuals produced in that population per unit time. The death rate, also called mortality rate, describes the number of individuals who die in a population per unit time. The immigration rate is the number of individuals who move into a population from a different area per unit time. The emigration rates describe the numbers of individuals who migrate out of the population per unit time.

The values of these four population parameters allow us to determine whether a population will increase or decrease in size. The "intrinsic rate of increase r " of a population is defined as

r = (*birth rate* + *immigration rate* +)-(*death rate* + *emigration rate*).

If r is positive, then more individuals will be added to the population than lost from it. Consequently, the population will increase in size. If r is negative, more individuals will be lost from the population than are being added to it, so the population will decrease in size. If r is exactly zero, then the population size is stable and does not change. A population whose density is not changing is said to be at **equilibrium** .

Population Models

We will now examine a series of population models, each of which is applicable to different environmental circumstances. We will also consider how closely population data from laboratory experiments and from studies of natural populations in the wild fit these models.

1.Exponential Growth

In this population model, it is assumed that the environmental conditions are absolutely supportive of the biological needs of the species which results in low mortality and high natality accompanied by progressive immigration from other areas. This leads to a high increase in the population of the species in that area. This model assumes that an environment has unlimited resources and can support an unlimited number of individuals. Although this assumption is clearly unrealistic in many circumstances, there are situations in which resources are in fact plentiful enough so that this model is applicable. Under these circumstances, the rate of growth of the population is constant and equal to the intrinsic rate of increase *r*.

This model is termed as the Exponential growth model. It is often called as the J-shaped growth as the graphical representation of the population growth resembles the letter “J”. The growth rate remains constant and does not depend on the population density due to which it is called also referred to as the **density-independent growth**.

Although it is rare to find an ecological niche that so abundantly supports the growth of a species it is not unheard of. However, this is not a sustainable growth and is inevitably followed by a population crash. The constant growth leads to a rapid exhaustion of resources to sustain life and consequently becomes uninhabitable by the species due to shortages.

2. Logistic Growth

This model of population growth is also known as **density-dependent growth** or the **S-shaped growth**. Logistic growth is also called "S-shaped growth" because the curve describing population density over time is S-shaped. In S-haped growth, the rate of growth of a population depends on the population's density. When the population size is small, the rate of growth is high. As population density increases, however, the rate of growth slows. Finally, when the population density reaches a certain point, the population stops growing and starts to decrease in size. Because the rate of growth of the population depends on the density of the population, logistic growth is also described as "density-dependent growth".

Under logistic growth, an examination of population size over time shows that, like J-shaped growth, population size increases slowly at first, then more quickly. Unlike exponential growth, however, this increase does not continue. Instead, growth slows and the population comes to a stable equilibrium at a fixed, maximum population density. This fixed maximum is called the

carrying capacity, and represents the maximum number of individuals that can be supported by the resources available in the given habitat. Carrying capacity is denoted by the variable *K*.

The fact that the carrying capacity represents a stable equilibrium for a population means that if individuals are added to a population above and beyond the carrying capacity, population size will decrease until it returns to *K*. On the other hand, if a population is smaller than the carrying capacity, it will increase in size until it reaches that carrying capacity. Note, however, that the carrying capacity may change over time. *K* depends on a wealth of factors, including both **abiotic** conditions and the impact of other biological organisms.

Logistic growth provides an accurate picture of the population dynamics of many species. It has been produced in laboratory situations in single-celled organisms and in fruit flies, often when populations are maintained in a limited space under constant environmental conditions

Biological species are sometimes placed on a continuum between *r* -selected and *k* -selected, depending on whether their population dynamics tend to correspond more to exponential or logistic growth. In *r* -selected species, there tend to be dramatic fluctuations, including periods of exponential growth followed by population crashes. These species are particularly suited to taking advantage of brief periods of great resource abundance, and are specialized for rapid growth and reproduction along with good capabilities for dispersing.

In *k* -selected species, population density is more stable, often because these species occupy fairly stable habitats. Because *k* -selected species exist at densities close to the carrying capacity of the environment, there is tremendous competition between individuals of the same species for limited resources. Consequently, *k* -selected individuals often have traits that maximize their competitive ability. Numerous biological traits are correlated to these two life history strategies.

3. Lotka-Volterra models.

It is also possible directly to consider between-species interactions in population dynamics models. Two that have been studied extensively are the Lotka-Volterra models, one for competition between two species and the other for interactions between predators and prey.

Competition describes a situation in which populations of two species utilize a resource that is in short supply. The Lotka-Volterra models of the population dynamics of competition show that there are two possible results: either the two competing species are able to **coexist** , or one species drives the other to extinction. These models have been tested thoroughly in the laboratory, often with competing yeasts or grain beetles.

Many examples of competitive elimination were observed in lab experiments. A species that survived fine in isolation would decline and then go extinct when another species was introduced into the same environment. Coexistence between two species was also produced in the laboratory. Interestingly, these experiments showed that the outcome of competition experiments depended greatly on the precise environmental circumstances provided. Slight changes in the environment—for example, in temperature—often affected the outcome in competitions between yeasts.

Studies in natural populations have shown that competition is fairly common. For example, the removal of one species often causes the abundance of species that share the same resources to increase.

Another important result that has been derived from the Lotka-Volterra competition equations is that two species can never share the same **niche** . If they use resources in exactly the same way, one will inevitably drive the other to extinction

When the density of population is low the growth rate is very high. But as the population density increases the growth slows down and finally reaches its saturation point and then starts to decrease in size. The starting phase in this population growth resembles that of the J-shaped or exponential growth rate. After some time however, it gains stability and remains constant. This represents the population that the environment in that area can support. It is termed as the **carrying capacity** and represents the maximum number that the habitat can support and sustain. If more individuals are added to the population then the population will start to decrease until it reaches the carrying capacity or equilibrium of that environment. The carrying capacity may, however, change with time depending on the biotic and abiotic conditions that prevail in the area.

Importance of the study of Population dynamics in Biology

1. It gives us an understanding of the link between the environmental changes and the subsequent changes in the population of a species.
2. It helps to find ways to curb the negative factor that is influencing the decline of a population.
3. With the growing global environmental changes, a number of species are on the brink of extinction. Population dynamics study helps the biologists identify these species and work towards the conservation of these endangered varieties of plant and animal life.
4. The high mortality rate and the low reproductive rates have led to an increasingly aging population which has become a threat to many animal species. Although migration is always an option for an animal species in order to reach an environment that is more habitable, a global downslide in the environmental conditions has left little chance for the migrating species to thrive in a different location.