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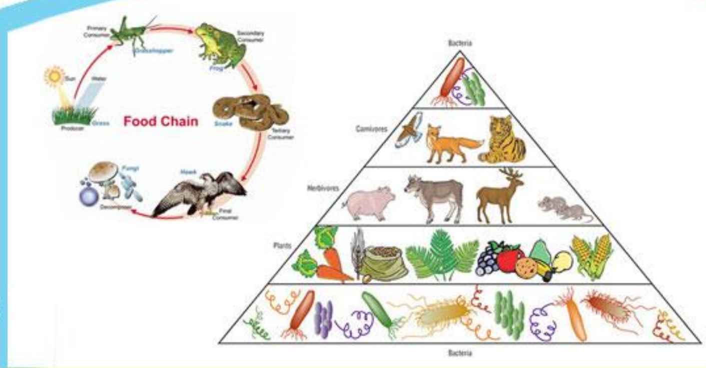
Subject: Environmental Sciences



Production of Coursework
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Paper No: 01 **Ecosystem Structures & Functions**

Module: 23 **Ecosystem Structure and Functions**

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Development Team

Principal Investigator & Co- Principal Investigator	**Prof. R.K. Kohli** **Prof. V.K. Garg & Prof. Ashok Dhawan** **Central University of Punjab, Bathinda**
Paper Coordinator	**Dr. Renuka Gupta, YMCA University of Science and Technology, Faridabad, Haryana**
Content Writer	**Dr. Sharda R. Gupta, former Professor of Botany Kurukshetra University, Kurukshetra**
Content Reviewer	**Prof. V.K. Garg** **Central University of Punjab, Bathinda**
Anchor Institute	**Central University of Punjab**

Description of Module	
Subject Name	**Environmental Sciences**
Paper Name	Ecosystem Structures & Functions
Module Name/Title	23. Structure and Functions of ecosystem
Module Id	EVS/ESF-I/23
Pre-requisites	
Objectives	To understand ecosystem components, structure, and functions
Keywords	Abiotic and biotic components, Ecosystem Structure and Boundary, Energy flow, Food chains and Foodwebs , Biogeochemical cycles, resistance and resilience stability, Photosynthesis , Decomposition, social–ecological systems, ecosystem services

Module 23 : Structure and Functions of Ecosystems

Learning Objectives

- To Understand ecosystem components and structure
- The key functional aspects of ecosystems
- Energy flow and elemental cycling are linked
- Concept of productivity and food webs
- Ecosystem regulation and stability
- Social–ecological systems, and ecosystem services

23.1. Introduction

The ecosystem has been a key organizational concept in ecology for many years, an important theoretical and applied concept for studying global change, and human environmental impacts. The ecosystem concept has provided a conceptual framework for studying nature and for sustainable management of natural resources (Odum, 1969; Aber et al., 1989; Vitousek et al., 1997). Ecosystem concept has proved to be of practical value to understand the complexity of natural systems and ecosystem properties. A lake, an island or a watershed are good examples of ecosystems in the context of systems theory of ecosystem analysis.

In 1935, A.G. Tansley, a British ecologist, defined an ecosystem as a basic unit of nature, composed of the set of organisms and physical factors forming the environment. Raymond Lindeman, while working on the Cedar Bog Lake in Minnesota,USA gave the trophic dynamic concept in 1942 and popularised the idea of the ecosystem as an energy transforming system. E.P. Odum has been one of the most influential ecologists of the twentieth century, laid foundations of the concept of ecosystem in ecological studies. It has been defined as a "basic functional unit of nature which includes organisms and their non-living environment, each interacting with the other and influencing each other's properties, and both necessary for maintenance and development of system" (Odum 1953). A more elaborate definition according to Odum (1971) is "the structural and functional unit of nature that includes all of the organisms (i.e., "the community") in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles". According to the CBD (Convention on Biological Diversity), an ecosystem is "a dynamic complex of plant, animal and micro-organism communities and their non-living environment, interacting as a functional unit", an integral component of which are humans (United Nations 1992; Article 2 of CBD). In all definitions, the concept of "interacting functional unit" in which living and non-living components of the ecosystem are variously coupled is emphasized.

Associated with the concept of ecosystem are those of structure and ecosystem functioning. Structure is related to the organization and distribution of elements within an ecosystem. Ecosystem functioning are related to the exchange of materials and the flow of energy in an ecosystem.

23.2 . Ecosystem Components and Structure

The ecosystem has two major kinds of components: (1) Abiotic (non-living) and (2) Biotic (living) components (Figs.23.1and 23.2**).**

2.1 Abiotic components

The abiotic structure is characterized by the quantity and distribution of non-living materials, edaphic factors and the climate regime (light, rainfall and temperature) (Figs.23.1and 23.2). The inorganic substances are carbon, nitrogen, oxygen, CO_2, and water, which are present in soil, water and air. The atmosphere supplies carbon and nitrogen, whereas soil minerals, and dissolved nutrients in water are a source of nutrients required by living organisms. The organic compounds such as proteins, carbohydrates, lipids, and other complex molecules, form a link between biotic and abiotic components of the system. The climatic factors like solar radiation and temperature determine the abiotic conditions within which organisms carry out their life functions. Soil is a medium of plant growth representing a mixture of minerals and organic matter, capable of supplying all the essential nutrients and water.

2.2 Biotic components

The organisms that make up the living part of the ecosystem (biotic community) are divisible into two major categories, viz., autotrophs (producers) and heterotrophs (consumers) (Figs.23.1and 23.2). This division is based on the function of the organisms.

2.2.1 Autotrophs: These are the chlorophyll bearing organisms which produce their own food by assimilating the solar energy and making use of the simple inorganic abiotic substances. In terrestrial ecosystems, the autotrophs are generally rooted plants (herbs, shrubs and trees). In open water such as deep aquatic ecosystems and oceans, the dominant producers are phytoplankton, which is -mostly microscopic organisms that float or drift in the water. In freshwater and marine ecosystems, algae and plants are the major producers near shorelines.

2.2.2 The heterotrophs: are the organisms, which cannot manufacture their own food. The heterotrophs are two types:

(i) Phagotrophs or macro-consumers: The macro-consumers include mainly the animals that ingest other organisms or particulate organic matter (e.g., snail that ingests organic particles). The food of consumers consists of organic compounds produced by other living organisms. The phagotrophs may be herbivores (ingesting plants, e.g., goat, deer), or carnivores (ingesting other animals - e.g., tiger, lion) or omnivores (ingesting both plants and animals, e.g. bear, man). A primary consumer that derives nutrition by eating plants is an herbivore. The secondary consumer or carnivore is an animal that preys upon an herbivore of other animals.

(ii)Microconsumers or saprotrophs: The saprotrophs are certain types of bacteria and fungi. These are also called decomposers, which break down complex dead organic matter in to simple inorganic forms, absorb some of the decomposition products, and release inorganic nutrients that are reused by the producers.

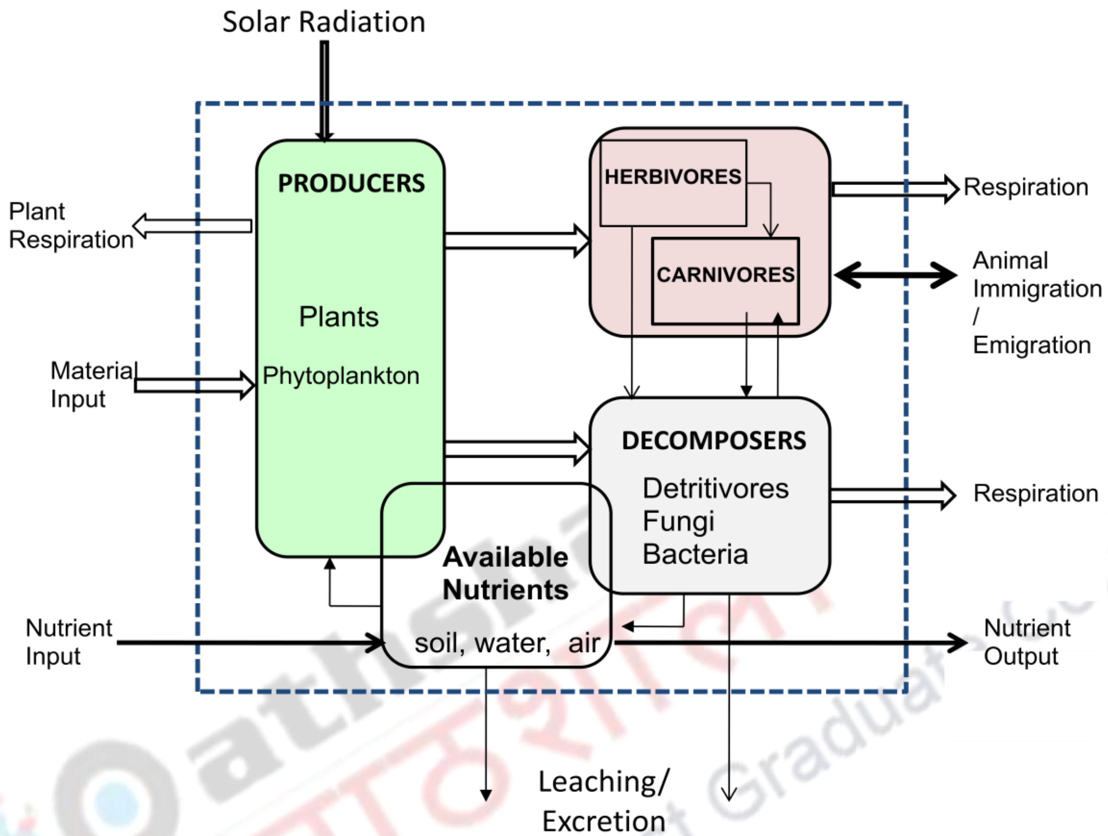


Fig.23.1. Schematic representation of an ecosystem showing abiotic and biotic components. The dashed lines represent the boundary of an ecosystem. **(based on Fath 2009)**

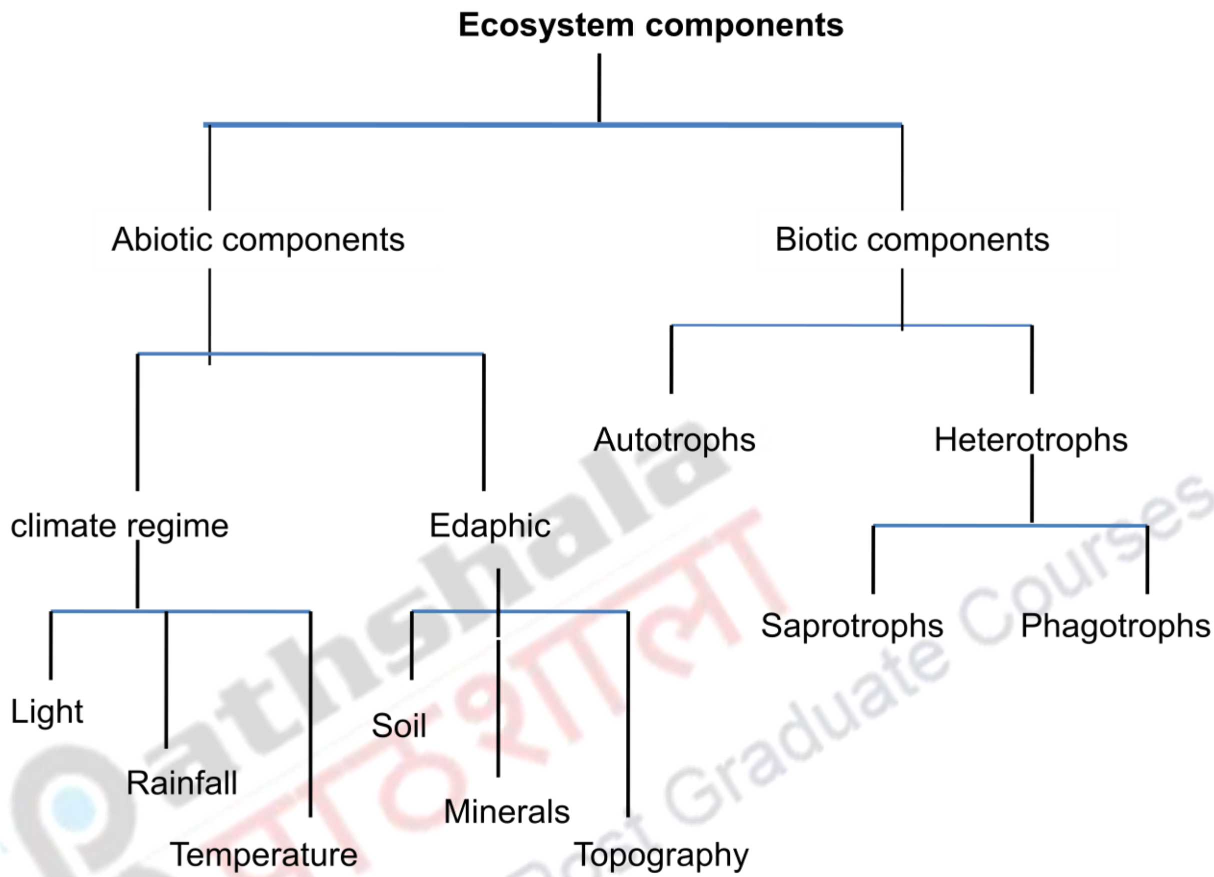


Fig. 23.2. Schematic representation of the ecosystem components

3. Ecosystem Structure

Ecosystem structure is a network of interactions between abiotic and biotic components of the system. The biotic structure of the ecosystem is characterized by the composition of the biological community including species numbers, biomass, life-form, life-history and spatial distribution of species. Species diversity at the levels of autotrophs, macroconsumers, and decomposers is an important structural characteristic of the ecosystems. The ecosystem level diversity refers to the complexity, showing the inter-relationships among the different functional groups of organisms. The structural aspects of ecosystems are discussed as follows:

3.1. Ecosystems at different spatial scales

Ecosystems may be considered to occur at different spatial scales, ranging from a single bacterium in soil, to a whole tropical forest ecosystem exhibiting stratification, a watershed, and the global ecosystem the whole Earth.

Ecosystems are hierarchically structured, which indicates that patterns manifest and processes operate at distinct spatial and temporal scales due to the interaction of abiotic and biotic components. A hierarchy of ecosystems ranging from a forest stand to a watershed and the whole landscape (comprised of mosaic of habitats) is shown in Figure 3.

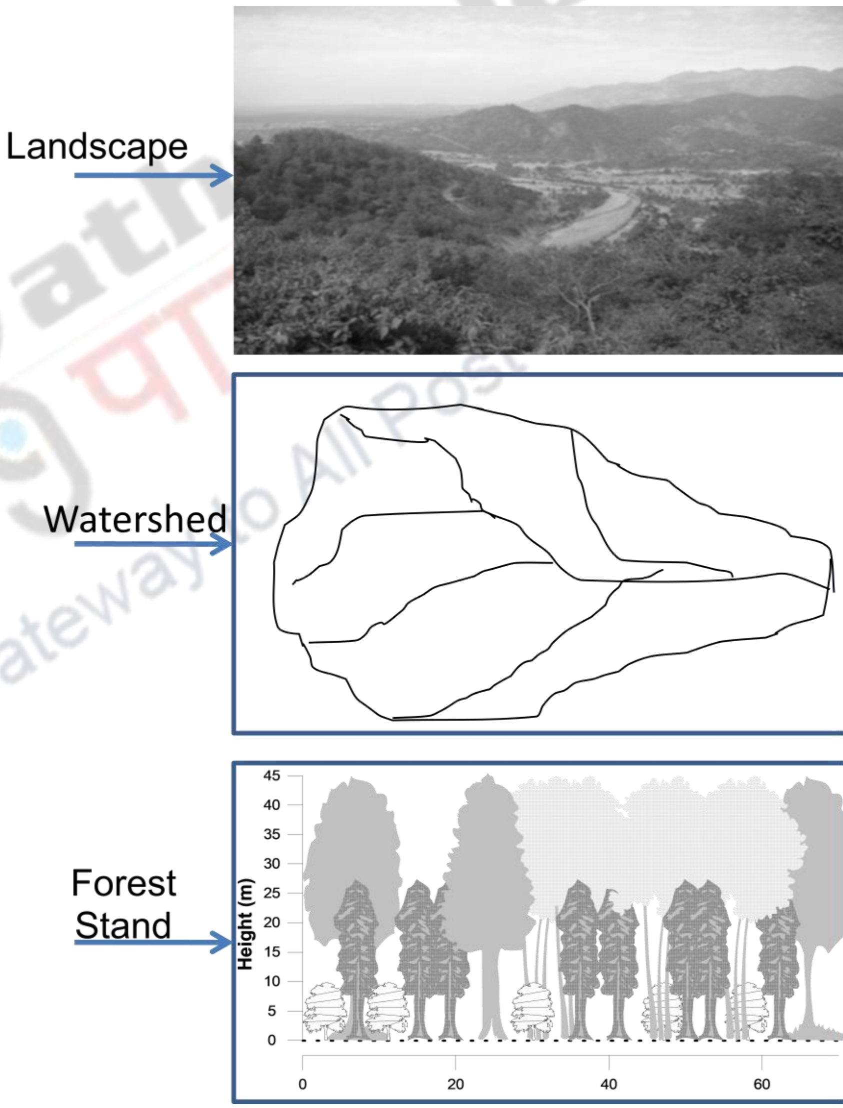


Fig.23.3. A hierarchy of ecosystems ranging from a forest ecosystem to a watershed and the whole landscape (consisting of mosaic of habitats) Source : Landscape photo SR Gupta ; Forest stand based on Singh et al.,2015).

23.3.2. Trophic structure

The trophic level of an organism is the position it occupies in a food web. Plants form the first trophic level, also known as primary producers, as they are able to convert solar energy into organic matter. The transfer energy occurs to the upper trophic levels through a number of food pathways, starting from plants. The uppermost trophic level includes top predators that have no other species predating on them. Thus, the food relationships between the structural components of the ecosystem, i.e., producers, consumers, and decomposers. Each trophic level may contain many species. These relationships facilitate the transfer of matter and energy between the living components of the system, and between them and non-living environment.

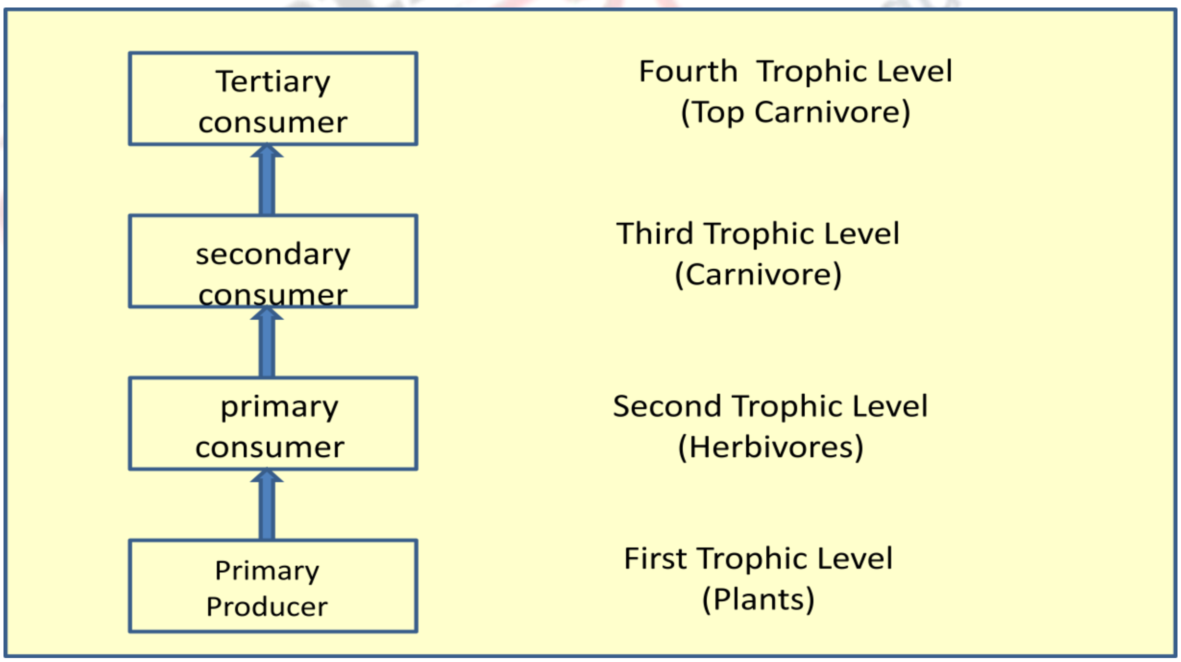


Fig.23.4. Schematic representation of trophic levels in an Ecosystem. Each trophic level may contain many species

23.3.3. Stratification

This refers to vertical structure of the organisms, which is a result of different environmental conditions (light, water ability, etc.). For example, a tropical rainforest exhibits vertical structure which consists of different strata of vegetation.

23.4. Ecosystem Boundary

In some cases, the boundaries of the ecosystem are reasonably "apparent", as is in the case of a pond or a lake. The pond or a lake also is always associated with a catchment or watershed, from which it receives the inflow of water as well as of a variety of inorganic and organic substances. As shown in Figure 4, the existence of the lake depends on its watershed, the entire drainage basin (lake + watershed) may be considered as a single ecosystem. Traditionally, earth's ecosystems have been divided into categories for comparing their structure and function.

Fig.23.5. A view of Renuka lake located in foothills of Siwaliks in Sirmaur district in western Himalaya. The lake and its watershed constitute a distinct ecosystem with its well defined boundary (Photo S.R. Gupta)

Investigators often define a boundary around an area to delimit a locale in which to study an ecosystem. For example, it could be the small watershed ecosystem that is useful to quantify inflows and outflows of water and dissolved elements. A watershed is the entire drainage of a stream or river, from which all the surface water and ground water leave at a single point. Watersheds have been used by scientists for measuring the input of rainwater collected at various locations within the watersheds and output in the streams that drain them. The watershed approach has been used by the ecologists at Hubbard Brook Forest of New Hampshire, a pioneering study to analyze nutrient cycling and regeneration processes for understanding how ecosystem functions (see Likens, 2013).

23. 5. Ecosystem Functions

Ecosystems exhibit a natural tendency to persist which has been made possible by a variety of functions performed by the structural components**.** 'Functions' refer to the biological, geochemical and physical processes that take place within an ecosystem. Ecosystems are thermodynamically open, which exhibit the exchange matter and energy with their environment. The key functional aspects of ecosystems are energy flow, food chains and food webs**,** biogeochemical cycling, ecosystem development**,** and ecosystem regulation and stability.

23.5.1 Energy flow

The green plants capture the solar energy and convert it through the process of photosynthesis into chemical energy of food and store it into their body. This process is called **primary productivity.** The rate of total capture of energy or total organic matter production by autotrophs (primary producers) is known as **gross primary production, Fig. 23.6.** The autotrophs use some of the energy they acquire for respiration. The remainder is the **net primary production**, the amount of energy left for the heterotrophic organisms. The energy is lost from the ecosystem when organic matter is oxidized back to CO_2 by the respiration of autotrophs and heterotrophs. At the trophic level of heterotrophs, the rate of assimilation of energy is called **secondary productivity.**

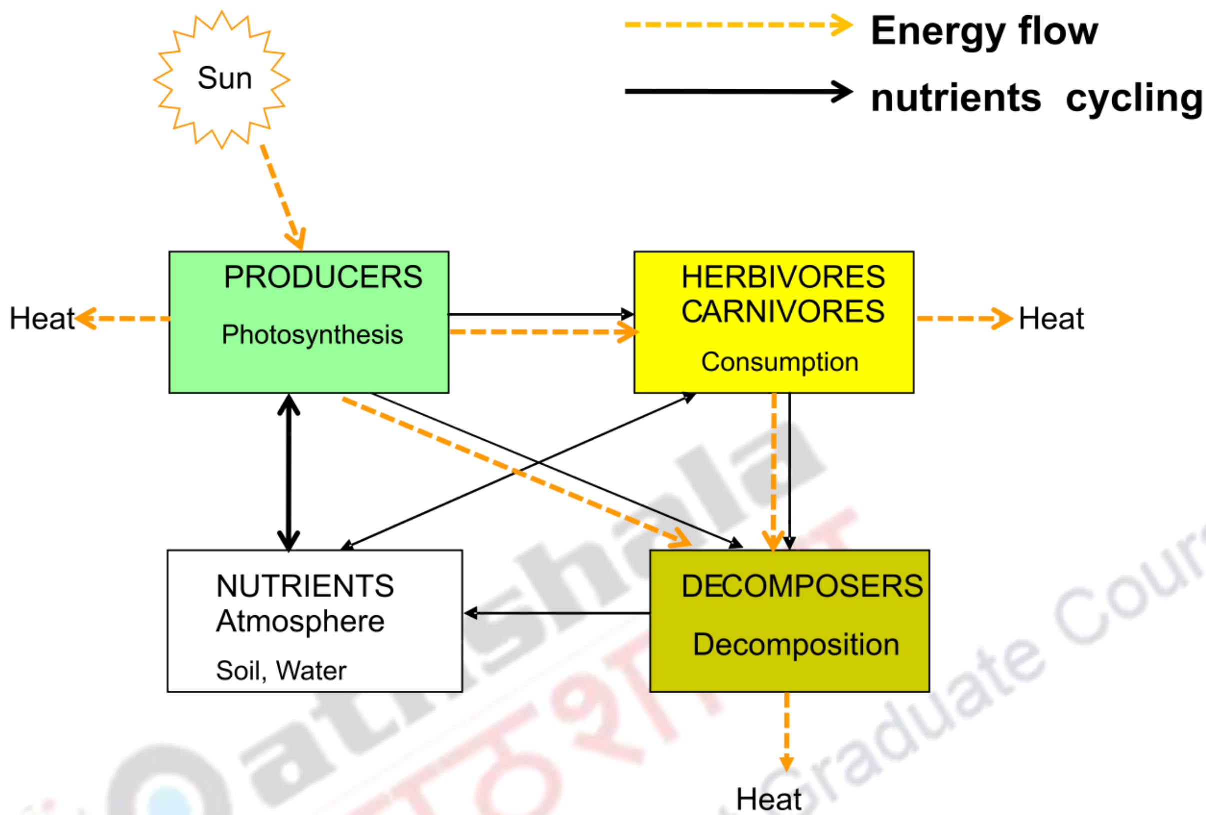


Fig23. 6 Schematic diagram showing unidirectional flow of energy and nutrients cycling in an ecosystem. (adapted from Singh et al.,2015)

Generally, primary productivity on land increases from Polar regions, to the equator except for the intervening strongly water-limited deserts. The greater productivity of tropical regions to a large extent is due to the favourable combination of high incident solar radiation, warm temperatures, abundant rainfall, and high biological diversity. These factors result into longer, almost year-round growing season. Aquatic **gross primary production** depends on the quantity of phytoplankton and the vertical profile of light and other physical factors. Microscopic phytoplanktons living in oceans are responsible for more than 40% of Earth's photosynthetic production, but the ecosystem with the greatest **net primary production** per unit area is the tropical rain forest.

5.2 Biogeochemical cycling

Nutrients move through the ecosystem in biogeochemical cycles**.** A chemical element moves through the biotic and the abiotic components of an ecosystem. Of the 30 to 40 elements necessary to life, six rank as the most important: carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus. These nutrients move from non-living to the living and back to the non-living again in a cyclic manner (Fig.23.6). The biogeochemical cycles are driven by energy flow and are crucial for the maintenance of life on earth in its present form. The biogeochemical cycles are of two basic types, viz., gaseous and sedimentary types. In the gaseous cycles (such as nitrogen and carbon) the reservoir is in the atmosphere or hydrosphere (ocean). In sedimentary types (for example, phosphorus cycle), the reservoir is in the lithosphere.

The nutrients are first taken up by the autotrophs, bound in the organic matter and move along the food chain to heterotrophic level and ultimately from all trophic levels, with the detritus, to the decomposer food-chain. The decomposers break down the complex organic compounds and release the nutrients to the soil from where they are again taken up by the plants. These biogeochemical cycles provide the foundation to understand how human activities lead to eutrophication (nutrient enrichment) and global climate change.

5.3 Food chains and Foodwebs

A trophic level is the position occupied by an organism in a food chain. A linear arrangement of trophic levels is called *food-chain* along which the energy flows (Fig. 23.7). At each trophic level some energy is lost as heat and respiration, as a result available energy decreases moving away from the first trophic level. Therefore, the number of trophic levels in a food chain is limited. The herbivorous animals derive the energy by ingesting plants or plant parts. These animals are eaten by carnivorous animals (first order carnivore) which in turn are eaten by other carnivorous animals (second order carnivore). In this chain of eating and being eaten away, the green plants form the first trophic level, the herbivores the second trophic level, and the carnivores constitute second order and the third trophic level, and so on.

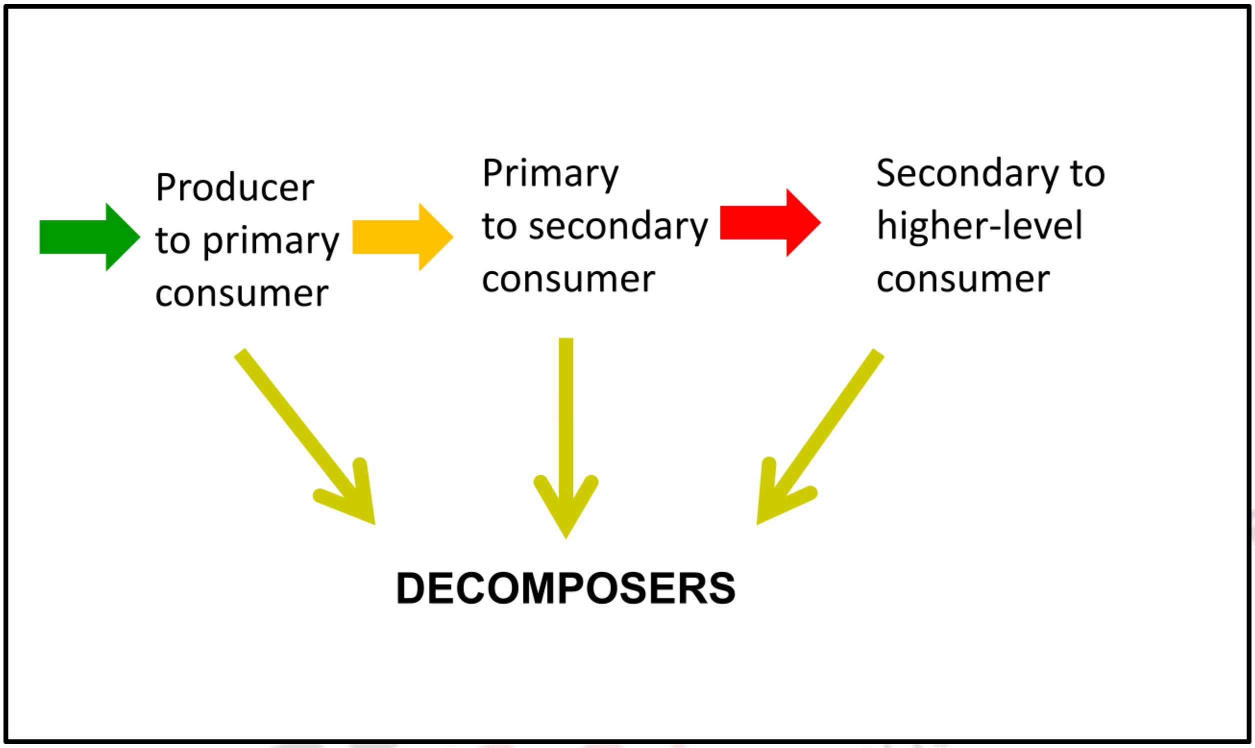


Fig.23.7. The transfers of matter and energy between producers, primary consumers (herbivores), secondary, or higher-level, consumers (carnivores), and decomposer

The food chains are of two types, i.e., Grazing food chain and Detritus food chain. The interlocking patterns of food chains in an ecosystem constitute the food webs**.** These are briefly described as follows:

Grazing food chain: The food chain that starts from green plants constitutes the grazing pathway

Green plants → herbivores → first order carnivores → second order carnivores

Some examples of grazing food chain in an ecosystem would be:

Grass → Rabbit → Fox

Phytoplanktons → Zooplanktons → Fish → Man

Detritus food chain: In many cases, the principal energy input is not green plants but dead organic matter. These are called detritus food chains. Examples of detritus food chains include the forest floor, a salt marsh, and the ocean floor in very deep areas.

Example of such a forest floor food chain is:

Dead leaves → Fungi → Collembola → Predatory mite

Detritivores get their nutrition by feeding on detritus, or freshly dead organisms, before they are fully decomposed. Detritus feeders include earthworms, some insects, hyenas, and vultures. In natural ecosystems, decomposers and detritivores eliminate the build up of plant litter, animal wastes, and dead plants and animals. Therefore, these organisms are the key to nutrient cycling.

Food Web: An ecosystem contains several food-chains, often these food chains are inter-linked forming a food web. Food webs provide another way to describe the flow of energy through ecosystems. A food web is a complex network of interconnected food chains. Food webs are useful in studies at the ecosystem level.

Elton's high Arctic 'food web' diagram is the classic study which has depicted major pathways of nutrient/energy flux and the interdependence between the terrestrial and aquatic ecosystems (Summerhayes and Elton, 1923). A more recent study has shown that there are the intricate food web relationships among different types of organisms in this high arctic region. A long-term study on invertebrate communities on W. Spitsbergen (500 km N of Bear Island), Svalbard has contributed a more detailed and realistic terrestrial food web based on a variety of published and unpublished data. The main characteristics of the food web worked out in this study are: (i) the presence of high number of species, (ii) the higher levels of connectivity among species, (iii) the occurrence of the significantly longer food chains. The simple vertebrate food web and its relationship to invertebrate food web for the high arctic region are shown Fig. 23.8.

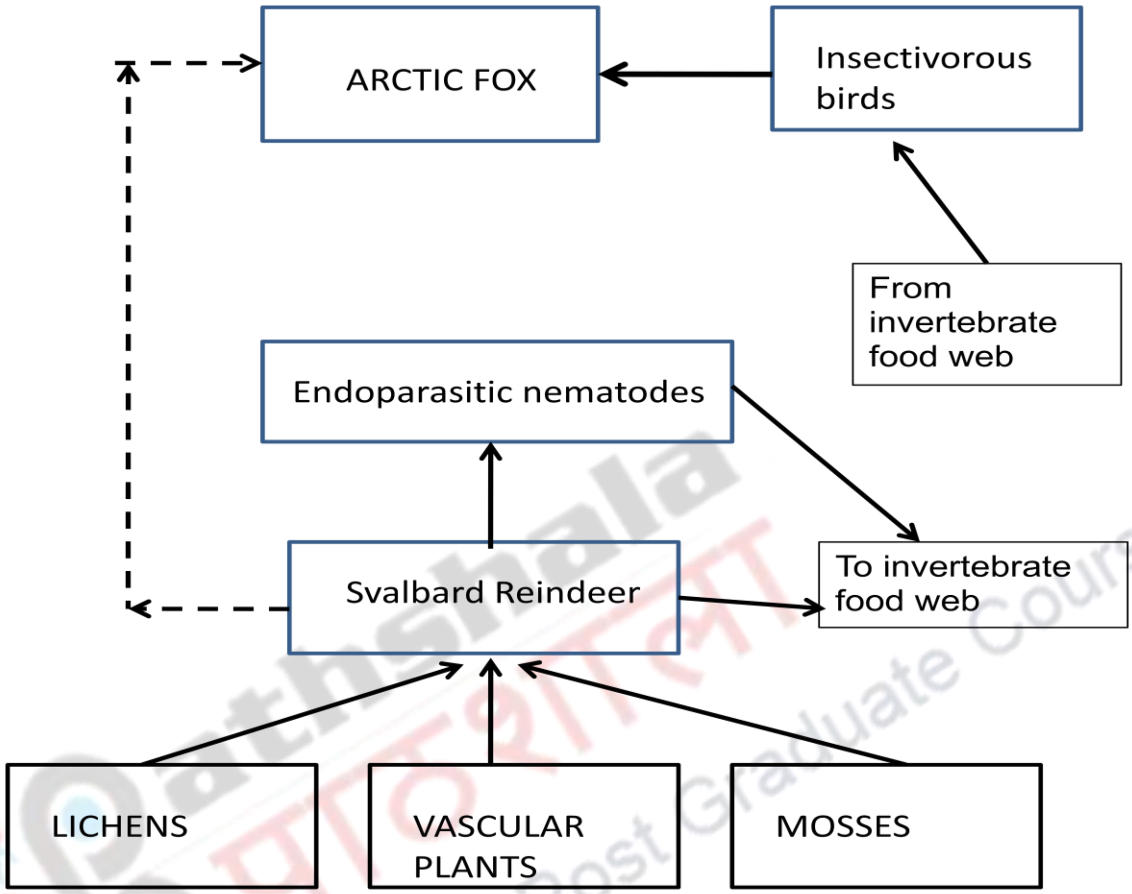


Fig. 23.8. Vertebrate food web for Bear Island (Bjørnøya), Svalbard in the high arctic region (based on Hodkinson and Coulson 2004)

Food-chain length representing the number of feeding links from a basal species to a top predator has been considered to be an important characteristic of food webs. The various hypotheses relating to food-chain length are: (i) the energy limitation hypothesis, (ii) the dynamic stability hypothesis, (iii) the optimal foraging hypothesis, (iv) the design constraint hypothesis (Pimm, 1982 and references therein). In addition, studies from both aquatic and terrestrial ecosystems suggest that food-chain length is positively correlated with habitat area suggesting another possible determinant of food-chain length (Pimm, 1982).

5.4 Ecosystem Development

The gradual change in species composition and processes of communities over time is known as ecological succession. As succession proceeds, changes occur not only in the biotic community but also in physical environment and overall structural and functional characteristics of ecosystems in a holistic manner. Thus, succession has been considered as ecosystem development that culminates in a stabilized ecosystem in which biomass and symbiotic function between organisms are maintained per unit of available energy flow (Odum 1969).

5.5. Ecosystem Regulation and Stability

Ecosystem is an open system with built-in homeostatic mechanisms. The ecosystem is an open system as well as a cybernetic system:

The ecosystem is an open system because of the requirement of an outside input in the form of solar radiation and an output to the environment (e.g. heat of respiration) for continued operation, (Fig.23.9a).

Cybernetic system: In open systems, when some of the output information may be fed back as input to control the functioning is called a cybernetic system. A system responds to inputs and has outputs, and a specialized kind of system response is called feedback **(**Fig. 23.9a). This feedback is of two types: positive feedback and negative feedback. In the positive feedback, increased output results in increased input and therefore in further increased output and so on. Reproduction is an example of positive feedback: births increase population size, which in turn increases the rate of reproduction, which leads to yet more births.

Negative feedback is one of the principal mechanisms of homeostasis- the maintenance of dynamic equilibrium by internal regulation .This decreases the amount of change and leads to stability and the state of dynamic equilibrium. Predator–prey systems are examples of negative feedback. Consumption of prey by a predator, for example, has a positive effect on the consumer but a negative effect on the prey. The negative effect of predators on prey prevents an uncontrolled growth of a predator's population, thereby stabilizing the population sizes of both predator and prey. If the negative feedbacks are weak or absent, population cycles can amplify and lead to extinction of one or both of the interacting species.

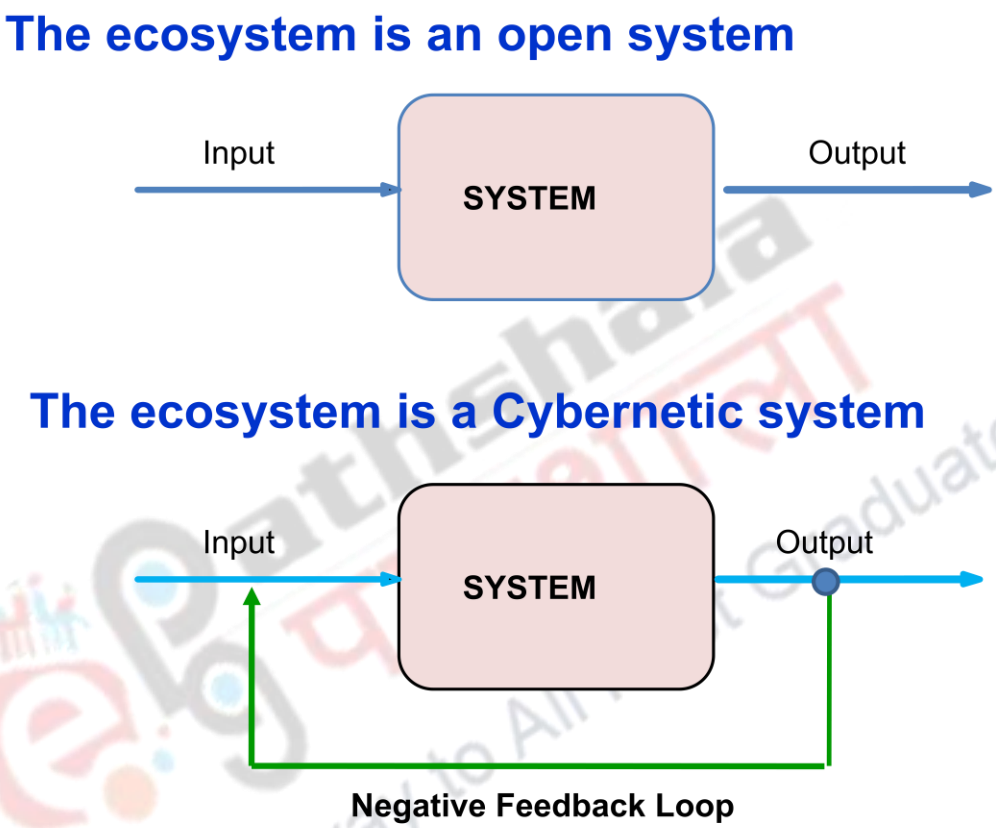


Fig. 9 An ecosystem is: (a) an open system receiving input of energy and having the output ;(b) a cybernetic system showing negative feedback control. (From Odum 1983)

Resilience and resistance stability

The ecosystem stability has two components: resistance and resilience (Holling 1973). The concept of resilience and resistance stability as applicable to an ecosystem is shown in Fig.23.10. The degree of deviation from normal operating range of the ecosystem function is **resistance** stability; the time required for recovery of normal processes from a disturbance is resilience **stability.** The resistance stability refers to the ability of the system to resist the forces that tend to cause it to leave its equilibrium. The resilience is the rapidity and ease with which the system returns to its original equilibrium state following perturbation or the time needed for the system to return to its pre-disturbance state.

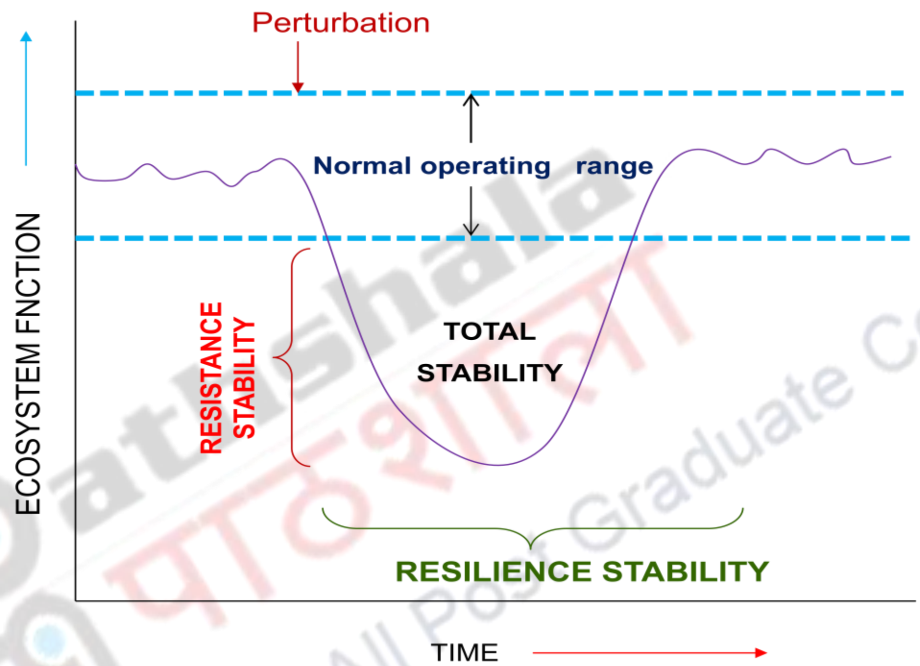


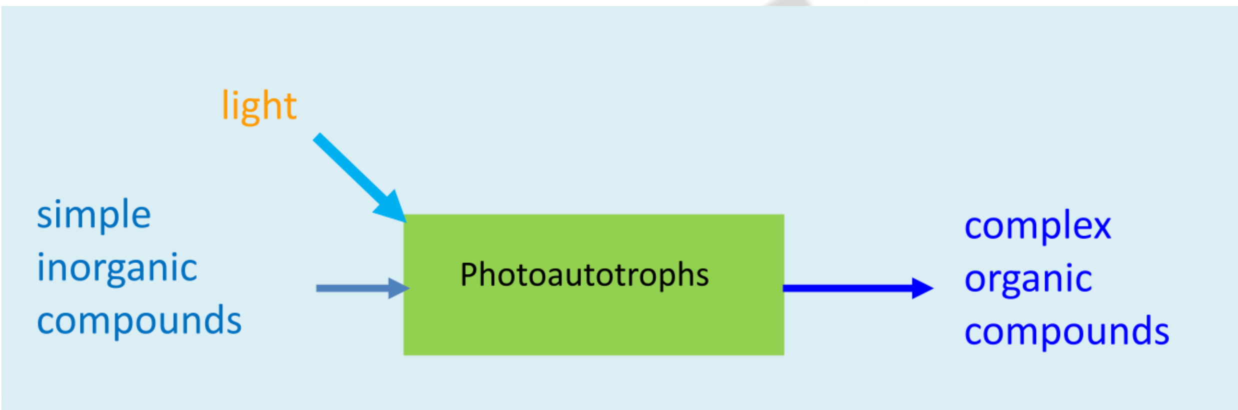
Fig. 23.10. The resistance and resilience stability of an ecosystem. (adapted from Odum 1983).

6. Ecosystem Processes

Ecosystem processes are the transfers of energy and materials from one compartment to another.. Fluxes involving biotic components include the absorption of minerals nutrients by plants, the decomposition of dead organic matter by soil microbes, the consumption of living plants or plant parts by herbivores and the consumption of herbivores by carnivores. The various ecosystem processes are briefly described as follows:

6.1 Photosynthesis

The functions are carried out in the ecosystem through the process of photosynthesis involved in primary productivity. Most carbon enters ecosystems through photosynthesis mediated by primary producers (plants on land and phytoplankton in aquatic ecosystems. Most producers capture photosynthetically active solar radiations to make carbohydrates (such as glucose, $C_6H_{12}O_6$) through the process of photosynthesis**.** In photosynthesis, energy enters the system in the form of sunlight and carbon enters as CO_2.



The actual fixation of CO_2 may be by one of the three different photosynthetic pathways:

C_3 photosynthetic pathway: About 85% of vascular-plant species fix carbon by the C_3 photosynthetic pathway, in which Rubisco is the primary carboxylating enzyme. CO_2 is initially bound to ribulose-1, 5-diphosphate (RuDP) through the action of the enzyme RuDP carboxylase (Rubisco). Current and future increase in CO_2 concentrations in the atmosphere provide C_3 grasses, shrubs, and trees with a marked positive effect on growth because of reductions in transpiration and stomatal conductance(Ainsworth and Rogers 2007).

C_4 photosynthetic pathway: About 3% of the global flora carries out photosynthesis by the C_4 photosynthetic pathway (Sage, 2004), and contributes about 23% of terrestrial gross primary productivity. C_4 species dominate many warm, high-light environments, particularly tropical grasslands and savannas. In C_4 photosynthesis, phosphoenolpyruvate (PEP) is first carboxylated by

PEP carboxylase in mesophyll cells to produce four-carbon organic acids. These organic acids are transported to specialized bundle sheath cells, where they are decarboxylated. The CO_2 released from the organic acids then enters the normal C_3 pathway of photosynthesis to produce sugars that are exported from the leaf.

Crassulacean acid metabolism: CAM is a photosynthetic pathway that enables plants to gain carbon under extremely dry conditions. About 10% of the earth's flora possesses CAM photosynthesis. Succulent plant species (e.g., cacti) grow in dry environments, many epiphytes in the canopies of tropical forests, gain carbon through CAM photosynthesis. CAM accounts for a small proportion of terrestrial carbon gain because it is active only under extremely dry conditions.

6.2. Chemosynthesis

A few producers, mostly chemosynthetic bacteria can convert simple compounds from their environment into more complex nutrient compounds without sunlight through the process of chemosynthesis. For example, the sulphur bacteria *Beggiatoa*, which are abundantly found in sulphur springs. The hydrothermal vents in some parts of ocean floor produce large amounts of superheated ocean water and hydrogen sulphide gas. In the dark and hot environment, specialized producer bacteria carry out chemosynthesis to convert inorganic hydrogen sulphide to nutrients, they require for their growth. The conversion of mineral-rich hydrothermal fluid into energy through the process of chemosynthesis is a key aspect of these unique ecosystems.

6.3 Respiration

The energy is lost from the ecosystem when organic matter is oxidized back to CO_2 by combustion or by the respiration of plants, animals, and microbes. The percentage of respiration, for example may be only around 25 per cent of gross primary production in a cornfield and as high as 50-70 per cent in some forests. The continual flow and degradation of energy through an ecosystem are essential for life to persist.

6.4 Decomposition

Decomposition concerns the breakdown of complex organic matter by decomposers to inorganic materials like carbon dioxide, water and various mineral nutrients. The surface layer of soil is the main site for decomposition processes in the ecosystem. Decomposition is a complex and multi step process of breaking down of complex organic matter by soil organisms to release free the nutrients for renewed uptake by the plants (Swift et al., 1979). During the process of litter decomposition, a large proportion of carbon is lost as respiration of decomposer organisms and nutrients are released during mineralization.

The resource cascade model of decomposition shows the participation of different substrates and soil biota in different phases of decomposition. "Decomposition is a process of equivalent importance as photosynthesis and needs to be understood in its full detail" (Heal et al., 1997). Most important factors affecting the rate of decomposition are moisture, temperature, and chemical composition of the substrate. Biodegradation of detritus in marine systems is attracting the attention of marine biologist to understand their role in oceanic carbon cycle, biological diversity and the importance of detritus food webs in nutrient regeneration in the oceans.

6.5 Herbivory and carnivory

Herbivory refers to ingestion of living plants or plant parts by heterotrophs, while carnivory refers to the ingestion of herbivores and other heterotrophs by animals. In a typical terrestrial ecosystem, herbivory may remove about 10% of net primary productivity; though percentage varies in different types of ecosystems. For example, the herbivory in different ecosystems amount to 2-3% for desert scrub, 4-7% for forest, 10-15% for temperate grasslands, 30-60% for tropical grasslands and grasslands managed for cattle raising (Singh et al., 2015).

The planet's largest animal, the blue whale, is a carnivore. The blue whale can reach 30 meters long and weigh as much as 200 tons. It feeds by taking huge gulps of water and then filtering out tiny shrimp-like creatures called krill. The blue whale can eat about 3.6 metric tons of krill every day. The biggest land based predator in the world is the polar bear, which feeds mainly on seals (*http://www.nationalgeographic.org/encyclopedia/carnivore/*).

Consumers also influence the ecosystems by affecting nutrient cycling. The role of herbivory in seed dispersal and plant diversity is well known. Studies have indicated that consumers play an active role in the maintenance and regulation of energy flow through the ecosystem and hence contribute to its persistence.

7. Integration of humans into ecosystem framework

Humans depend on ecosystem properties and on the network of interactions among organisms and within and among ecosystems for sustenance, just like all other species. In performing various functions, ecosystems provide materials to humans in the form of food, fiber, and building materials and they contribute to the regulation of soil, air, and water quality. Integration of humans and their socio-economic needs into ecosystem framework is essential for ecological sustainability. As shown in Figure 23.11, the ecosystem resources and services are dependent on energy, biogeochemical and hydrological cycles and the various types of human uses, which have an effect on these flows. Human activities have an increasing impact on all the processes that govern ecosystem properties. The human use of ecosystem services and support depends on the proper functioning of local ecosystems linked to other multifunctional ecosystems (Folke, 1998). The social-ecological systems approach emphasizes that people, communities, economies, societies, and cultures are an integral part of the biosphere and shape it, from local to global scales (Steffen et al., 2004). It is now clear that the genetic and species diversity making up the biosphere allows it to persist and adapt under changing conditions (Mace et al., 2014).

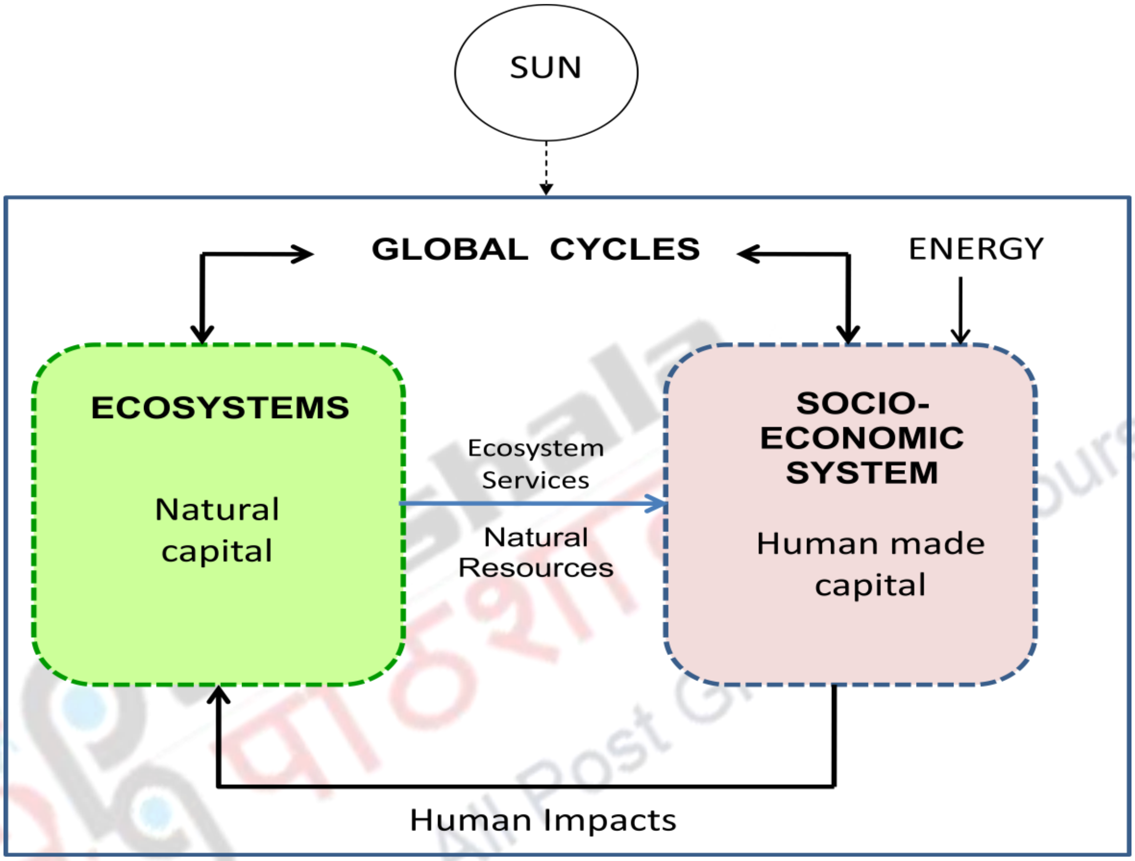


Figure 23.11. The relationship of natural ecosystems and the human system. The global cycles are the hydrological and biogeochemical cycles. There are cross scale interactions between various flows, natural resources and ecosystem services (based on Folke 1998)

8. Ecosystem Services

Ecosystem services are the benefits people obtain from ecosystems. The Millennium Ecosystem Assessment (MEA) distinguished four broad categories of ecosystem services, i.e., provisioning, regulating, cultural, and supporting services (MA, 2005). The provisioning services describe the processes that yield foods, fibers, fuels, freshwater, biochemicals (medicinal plants, pharmaceuticals), and genetic resources. The cultural services comprise a set of largely non-material benefits of the ecosystems including recreation and tourism and the spiritual, religious, esthetic, and inspirational well-being. The regulating services are the benefits obtained from regulation of ecosystem processes; include pollination, water purification, and waste treatment; air quality maintenance, climate regulation, hydrological flows, and disease regulation. The supporting services are those that are necessary for the production of all other ecosystem services (MA, 2005), The supporting services differ from provisioning, regulating, and cultural services in that their impacts on people are indirect.

23.9. Summary

i. Ecosystem constitutes a dynamic complex of plant, animal and micro-organism communities and their non-living environment, interacting as a functional unit (e.g., a lake, grassland, or a forest ecosystem).
ii. The ecosystem has biotic and abiotic components. Abiotic components are non-living, biotic components are the living organisms (biotic community).
iii. Ecosystem structure is a network of interactions between abiotic and biotic components of the system.
iv. Spatial scale refers to the distribution of ecosystems in space.
v. The rate of total organic matter production by autotrophs through the process of photosynthesis is known as gross **primary production.**
vi. Consumers are herbivores, carnivores, omnivores, or decomposers. Decomposers recycle nutrients back to the producers by decomposing the wastes and remains of other organisms.
vii. Nutrients move through the ecosystem in biogeochemical cycles (gaseous and sedimentary types).
viii. During ecosystem development, changes occur in physical environment and overall structural and functional characteristics of ecosystems over a period of time.
ix. The degree of deviation from normal operating range of the ecosystem function is resistance stability; the time required for recovery of normal processes is resilience stability..
x. Ecosystem processes are the transfers of energy and materials from one pool to another. The various ecosystem processes are photosynthesis, respiration, and decomposition, herbivory and carnivory.

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