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VOL. I

Geography and Economics

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CHAPTER 8
THE CYCLING OF MATTERS AND ENERGY IN ECOSYSTEMS

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INTRODUCTION

Ecosystems on earth contain diverse forms of life and have unique needs to sustain these life-forms. An ecosystem is composed habitats, each made up of biotic and abiotic factors. An ecosystem has been defined as a dynamic entity composed of a biological community and its associated abiotic environment. Often the dynamic interactions that occur within an ecosystem are numerous and complex. Ecosystems are also always undergoing alterations to their biotic and abiotic components (Pidwny,2020).

Growth in human populations increased conversion of natural ecosystems to agricultural, industrial, residential use and demand for ecosystem inputs, such as fresh water, fiber, and soil fertility, as well as increased pressure on the capacity of natural ecosystems. Deforestation, expanding agriculture, illegal fishing and hunting, unplanned tourism, and pollution by pesticides have also caused a progressive deterioration of natural habitats (Shende et al.,2015).

Human activities have mobilized Earth elements and accelerated their cycles. For example, more than double the amount of reactive nitrogen that has been added to the bio-sphere since pre-industrial times (Galloway et al.,2014). Human activities have increased atmospheric carbon dioxide by about 40% over pre-industrial levels and more than doubled the amount of nitrogen available to ecosystems. Similar trends have been observed for phosphorus and other elements, and these changes have major consequences for biogeochemical cycles and climate change.

Concept of an Ecosystem:

The term ecosystem was coined in 1935 by the Oxford ecologist Arthur Tansley to encompass the interactions among biotic and abiotic components of the environment at a given site. The living and non-living components of an ecosystem are known as biotic and abiotic components, respectively. Ecosystem was defined in its presently accepted form by Eugene Odum as, "an unit that includes all 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, i.e., exchange of materials between living and non-living, within the system".(Odum,1968). The ecosystem is the set of species in a given area that interact among themselves. They interact through processes such as predation, parasitism, competition and symbiosis as well as with their abiotic environment to disintegrate and become part of cycles of energy and nutrients. The species of the ecosystem, including bacteria, fungi, plants and animals are dependent on each other. The relationships between species and their environment facilitate the flow of matter and energy within the ecosystem (Willis, 1997).

According to Rusell *et al.*, (1993), the relevance of the ecosystem concept to geography cannot be overemphasized since it provides not only a means of describing, analyzing and understanding a wide variety of problems in physical geography, but also provides a theoretical framework and approach which can be validly used in human geography. The

and regulating air and water quality. Ecological processes, such as primary production, influence the extent, distribution, andbiodiversity of systems (MEA.2005).

There are four ecosystem processes that are fundamental to all terrestrial ecosystems:

1. **The Water Cycle**: The constant process of precipitation, transpiration, evaporation, and surface and ground water flow is called the water cycle. The effectiveness of the water cycle and its overall functioning are directly influenced by land management practices.
2. **The Mineral Cycle:** The mineral cycle may also be referred to as the nutrient cycle. Nutrients follow cyclical patterns as they are used and re-used by all living organisms. Physical processes such as oxidation, photo-decay, mechanical breakage, fire, and actions of wind and water are non-biological facets of the mineral cycle. The manner and rate at which nutrients are cycled play a critical role in ecosystem health and are directly influenced by land management practices.
3. **Plant and Animal Succession**: The process of change is the only constant in all ecosystems. Populations of plants and animals change continually in response to all sorts of environmental pressures. This is how the composition and structure of an ecosystem changes following a disturbance (succession). Wayne and Kauffman (1994) described the four processes (water cycle, nutrient cycle, energy flow and community dynamics) of the ecosystem as four different windows through which a room can be viewed.
4. **Energy Flow:** This flow of energy in our ecosystems is sometimes referred to as the carbon cycle because carbon is involved in all energy storage and transfer. Energy flow is closely related to the other ecosystem processes that is the water cycling, mineral cycling, and succession. It in fact drives these activities and makes them possible. Energy flow is a critical process on rangelands and is directly influenced by land management practices

Biogeochemical cycles

Biogeochemical cycles involve the fluxes of chemical elements among different parts of the Earth: from living to non-living, from the atmosphere to the land and sea, and from soils to plants. They are called "cycles" because matter is always conserved and because elements move to and from major pools via a variety of two-way fluxes, although some elements are stored in locations or in forms that are differentially accessible to living things (Galloway et al.,2014). The word "Biogeochemical" is a combination of three words which are "Bio" - living, "Geo" - earth - rock, "Chemical" - element. It involves movement of nutrient elements through the various components of an ecosystem. Biogeochemical cycles are components of the broader cycle that govern the functioning of planet Earth. The Earth is a system open to electromagnetic radiation from the sun and outer space, but is a virtually closed system with regard to matter. This means that the planet has minimal flux of matter, other than meteorite collisions and minor amounts of intergalactic particle trapping (or loss) by the upper atmosphere. Therefore, matter that earth contained from the time of its birth is transformed and circulated geographically. This is in line with the law of conservation of matter which states that matter cannot be created nor destroyed but can be transformed including the transformation between matter and energy (Moses, 2012). There are more than 40 elements required for the various life processes by plants and animals; that it's proper growth and development. According to Lavelle *et al.*, (2009), there are at least 16

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essential chemical elements for plant growth. Carbon, hydrogen, and oxygen, obtained in large amounts from air and water, make up the bulk of plant dry matter in the products of photosynthesis, but usually are not included as "nutrient" elements.

Nitrogen (N), ***Phosphorus*** (P), ***Potassium*** (K), ***Calcium*** (Ca), ***Magnesium*** (Mg), ***Sulfur*** (S), ***Iron*** (Fe), ***Manganese*** (Mn), ***Zinc*** (Zn), ***Copper*** (Cu), ***Boron*** (B), ***Molybdenum*** (Mo), and ***Chlorine*** (Cl) *are obtained from the soil and required by all plants.*

These elements are continuously cycling in the ecosystem through the biogeochemical cycles and the planet earth has no input of these nutrients. The nutrients (matter) from the dead remains of organisms are recovered and made available to the producers by decomposers. Thus, the nutrients are never lost from the ecosystems.

Types of Biogeochemical cycles

Hydrologic or Water cycle: Water is the most important chemical of life for all living organisms on earth. Ninety three percent of water on earth is in solid state mainly comprising the ice caps and glaciers of Polar Regions. Water is the basis of all living processes. The human body is more than 1/2 water and human cells are more than 70 percent water. Thus, most land animals need a supply of fresh water to survive. However, when examining the stores of water on Earth, 97.5 percent of it is non-potable salt water (Figure 1). Of the remaining water, 99 percent is locked underground as water or as ice. Thus, less than 1 percent of fresh water is easily accessible from lakes and rivers. Many living things, such as plants, animals, and fungi, are dependent on the small amount of fresh surface water supply, a lack of which can have massive effects on ecosystem dynamics (Bear,2020). There are various processes that occur during the cycling of water, these processes include the evaporation/sublimation, condensation/precipitation, subsurface water flow, surface runoff/snowmelt and stream flow.

The water cycle is driven by the sun's energy as it warms the oceans and other surface waters. This leads to the evaporation (water to water vapor) of liquid surface water and the sublimation (ice to water vapor) of frozen water, which deposits large amounts of water vapor into the atmosphere. Over time, this water vapor condenses into clouds as liquid or frozen droplets and is eventually followed by precipitation (rain or snow), which returns water to the Earth's surface. Rain eventually permeates into the ground, where it may evaporate again if it is near the surface, flow beneath the surface, or be stored for long periods. More easily observed is surface runoff: the flow of fresh water either from rain or melting ice. Runoff can then make its way through streams and lakes to the oceans or flow directly to the oceans themselves (Figure 1)

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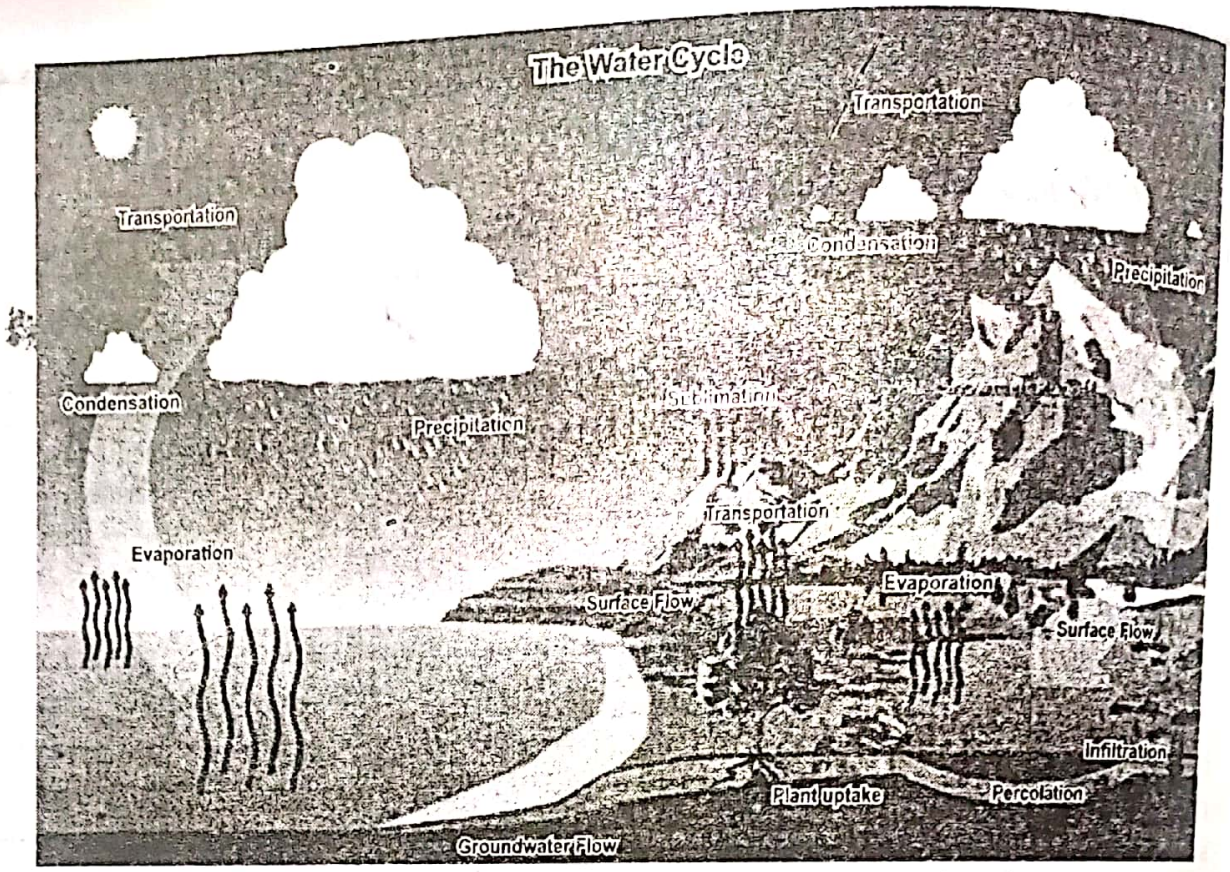


Figure 1: The Water cycle (Source: Adopted from Bear (2020)

1. Gaseous cycle (It includes atmospheric Oxygen, Carbon and Nitrogen cycles)

   i. **The Carbon Cycle:** Carbon is the second most abundant element in living organisms. Carbon is present in all organic molecules, and its role in the structure of macromolecules is of primary importance to living organisms. Carbon compounds contain especially high energy, particularly those derived from fossilized organisms, mainly plants, which humans use as fuel (Bear, 2020). Carbon is one of the most important elements that sustain life on earth. Carbon dioxide and methane gases (compounds of carbon) in the earth's atmosphere has a substantial effect on earth's heat balance. It absorbs infrared radiation and hence may contribute to global warming and climate change.

According to Ciais *et al.,* (2013), the global carbon cycle can be viewed as a series of reservoirs of carbon in the earth System, which are connected by exchange fluxes of carbon. Conceptually, one can distinguish two domains in the global carbon cycle. The first is a fast domain with large exchange fluxes and relatively 'rapid' reservoir turnovers, which consists of carbon in the atmosphere, the ocean, surface ocean sediments and on land in vegetation, soils and freshwaters. A second, slow domain consists of the huge carbon stores in rocks and sediments which exchange carbon with the fast domain through volcanic emissions of CO_2, chemical weathering, erosion and sediment formation on the sea floor (Figure 2). Carbon dioxide gas exists in the atmosphere and is dissolved in water. Photosynthesis converts carbon dioxide gas to organic carbon, and respiration cycles the organic carbon back into carbon dioxide gas. Long-term storage of organic carbon occurs when matter from living organisms is buried deep underground and becomes fossilized.

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Volcanic activity and, more recently, human emissions, bring this stored carbon back into the carbon cycle

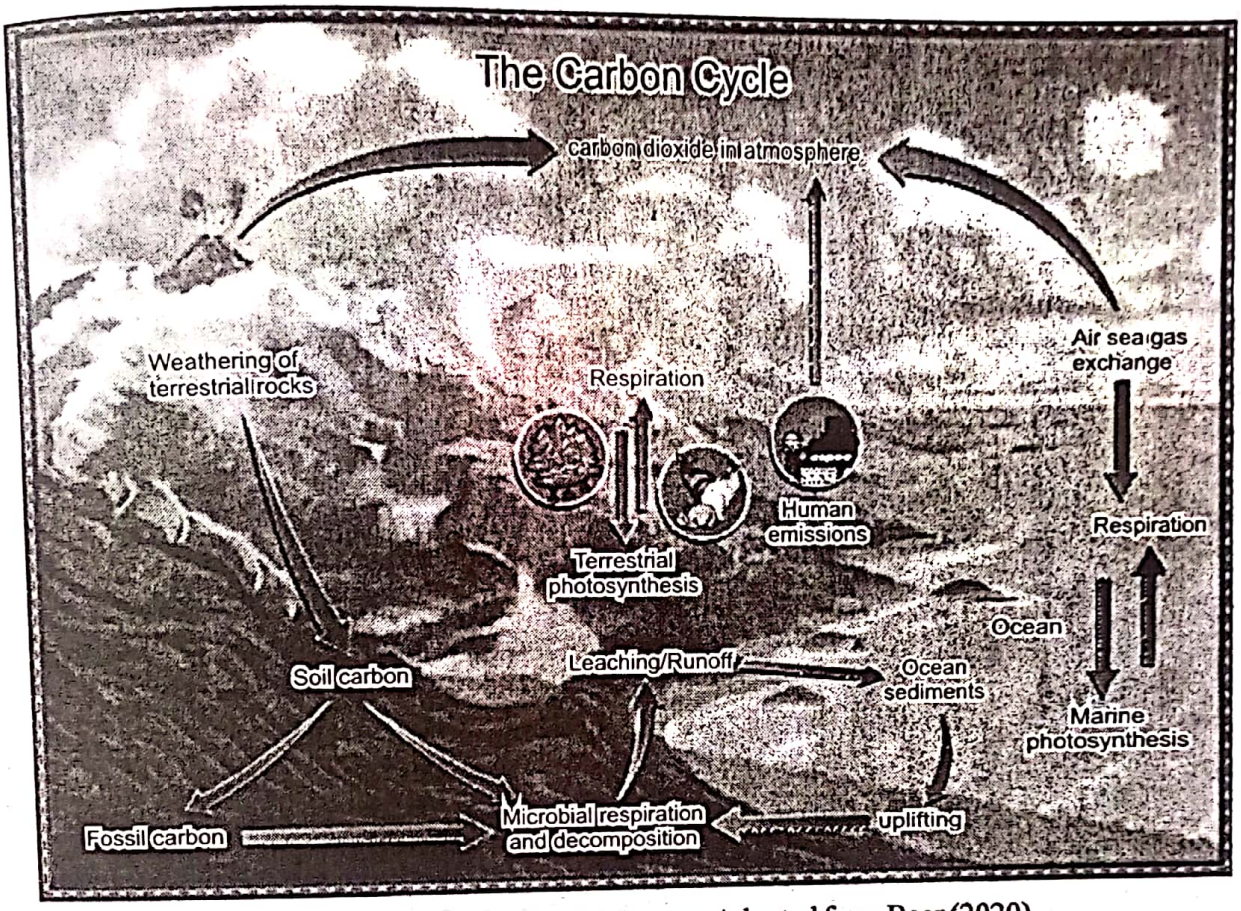


Figure 2: The Carbon Cycle (Source: Adopted from Bear (2020)

ii. **The Nitrogen Cycle:-** Nitrogen gas is the most abundant element in the atmosphere and all the nitrogen found in terrestrial ecosystems originate from the atmosphere. The nitrogen cycle is by far the most important nutrient cycle for plant life. Plants and phytoplankton are not equipped to incorporate nitrogen from the atmosphere (which exists as tightly bonded, triple covalent N_2) even though this molecule comprises approximately 78 percent of the atmosphere.

Nitrogen enters the living world via free-living and symbiotic bacteria, which incorporate nitrogen into their macromolecules through nitrogen fixation (conversion of N_2). Cyanobacteria live in most aquatic ecosystems where sunlight is present; they play a key role in nitrogen fixation. Cyanobacteria are able to use inorganic sources of nitrogen to "fix" nitrogen. *Rhizobium* bacteria live symbiotically in the root nodules of legumes (such as peas, beans, and peanuts) and provide them with the organic nitrogen they need. Free-living bacteria, such as *Azotobacter*, are also important nitrogen fixers. In addition, humans industrially fix nitrogen to produce artificial fertilizers. Organic nitrogen is especially important to the study of ecosystem dynamics since many ecosystem processes, such as primary production and decomposition, are limited by the available supply of nitrogen. As shown in Figure 3, the nitrogen that enters living systems by nitrogen fixation is

successively converted from organic nitrogen back into nitrogen gas by bacteria. This process occurs in three steps in terrestrial systems: ammonification, nitrification, and denitrification.

First, the ammonification process converts nitrogenous waste from living animals or from the remains of dead animals into ammonium (NH_4^+) by certain bacteria and fungi. Second, the ammonium is converted to nitrites (NO_2^-) by nitrifying bacteria, such as *Nitrosomonas*, through nitrification. Subsequently, nitrites are converted to nitrates (NO_3^-) by similar organisms. Third, the process of denitrification occurs, whereby bacteria, such as *Pseudomonas* and *Clostridium*, convert the nitrates into nitrogen gas, allowing it to re-enter the atmosphere

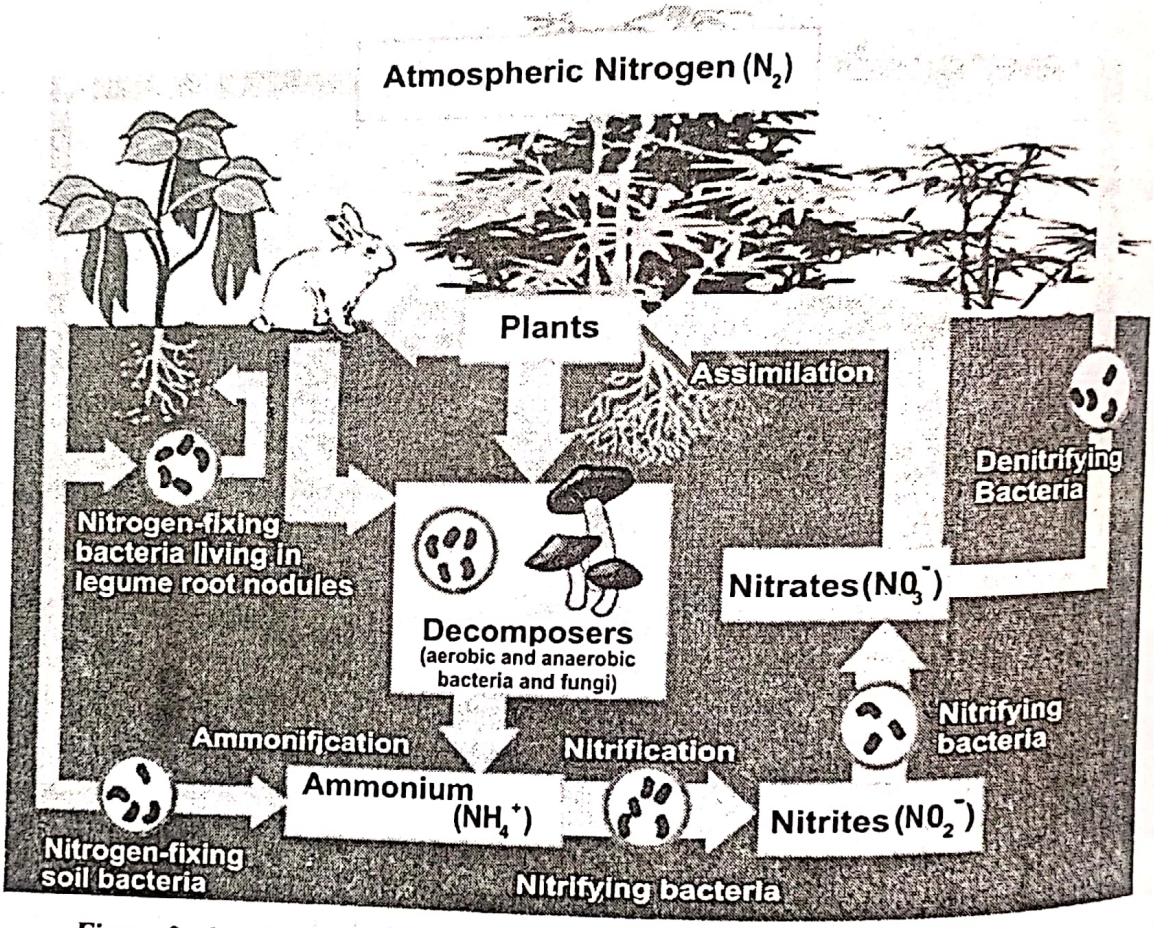


Figure 3: the Nitrogen Cycle (Source: Environmental Protection Agency (2009)

2. Sedimentary cycle – It includes the cycles of Phosphorus, Sulphur and Calcium - Which are present as sediments of earth.

i. **The Phosphorus Cycle:-** Phosphorus is commonly found in water, soil and sediments. Phosphorus cannot be found in air in the gaseous state. This is because phosphorus is usually a liquid at standard temperatures and pressures. Phosphorus is mainly cycled through water, soil and sediments. However, very small particles in the atmosphere may contain phosphorus or its compounds. Phosphorus moves slowly from deposits on land and in sediments, to living organisms, and much more slowly back into the soil and water sediment. The phosphorus cycle is the slowest one of the sedimentary cycles. According to Bear *et al.*,(2020), phosphorus is

another essential nutrient for living processes; it is a major component of nucleic acids, phospholipids, and, as calcium phosphate, makes up the supportive components of our bones. Phosphorus is often the limiting nutrient (necessary for growth) in aquatic ecosystems (Figure 4). Phosphorus occurs in nature as the phosphate ion (PO_4^{3-}). In addition to phosphate runoff as a result of human activity (mined and used to make a artificial fertilizer), natural surface runoff occurs when it is leached from phosphate-containing rock by weathering, thus sending phosphates into rivers, lakes, and the ocean. This rock has its origins in the ocean. Phosphate-containing ocean sediments form primarily from the bodies of ocean organisms and from their excretions. However, in remote regions, volcanic ash, aerosols, and mineral dust may also be significant phosphate sources. This sediment then is moved to land over geologic time by the uplifting of areas of the Earth's surface.

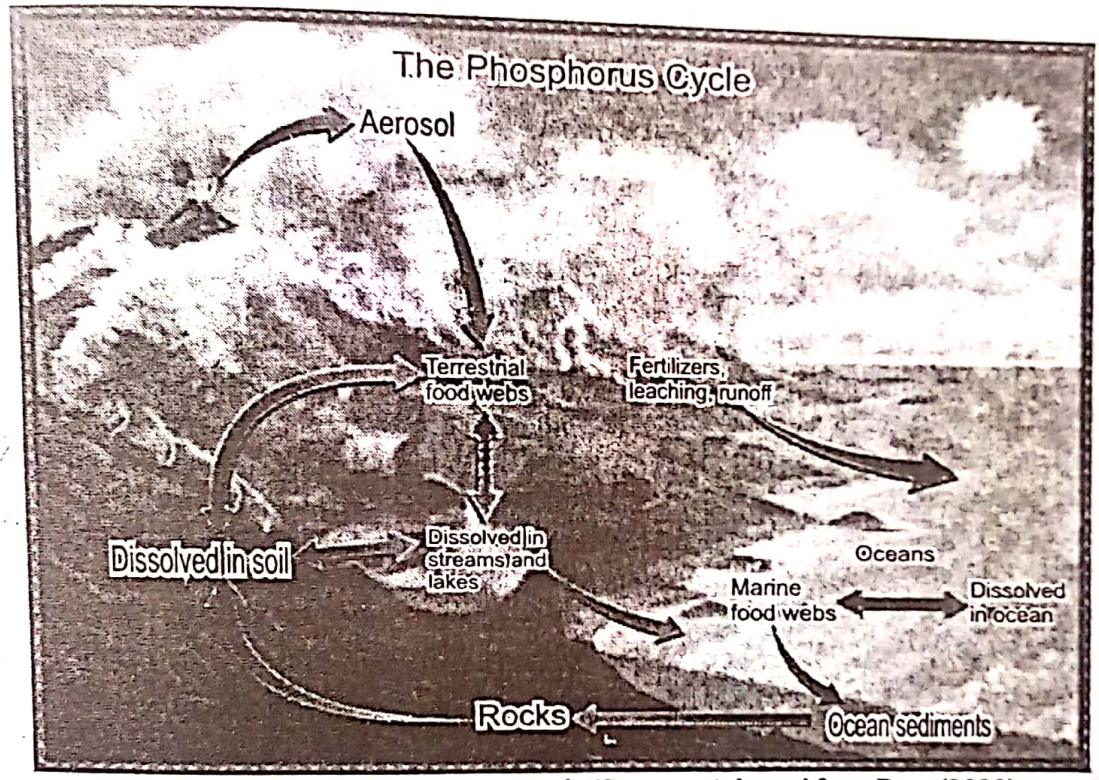


Figure 4: The Phosphorus Cycle (Sources: Adopted from Bear (2020)

The importance of biogeochemical cycles

1. **Biogeochemical cycles** enable the transformation of matter from one form to another. This transformation enables the utilization of matter in a form specific to particular organisms. For example, humans utilize water in liquid form. Through the hydrological cycle, water vapor is condensed to liquid and ice converted to liquid water. Nitrogen, despite its abundance in the atmosphere it's often the most limiting nutrient for plant growth. This problem occurs because most plants can only take up nitrogen in two solid forms: ammonium ion (NH4+) and the ion nitrate (NO3-). Therefore, biogeochemical cycles enable the provision of elements to organisms in utilizable forms.
2. **Biogeochemical cycles** enable the transfer of molecules from one locality to another. Some elements such as nitrogen are highly concentrated in the atmosphere, but some of the atmospheric nitrogen is transferred to soil through the nitrogen cycle (which is a biogeochemical cycle).

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3. **Biogeochemical cycles** facilitate the storage of elements. Elements carried through the biogeochemical cycles are stored in their natural reservoirs, and are released to organisms in small consumable amounts. For example, through the nitrogen cycle and with the help of the nitrogen fixing bacteria, green plants are able to utilize nitrogen in bits though it is abundant in the atmosphere.

4. **Biogeochemical cycles** assist in functioning of ecosystems. An ecosystem is a system that properly functions in a state of equilibrium, and whenever any imbalances occur, the ecosystem through the biogeochemical cycles restores to the equilibrium state; this may take a few days or many years. The adjustment is such that the disturbing factor is eliminated.

5. **Biogeochemical cycles** link living organisms with living organisms, living organisms with the non-living organisms and nonliving organisms with non-living organism. This is because all organisms depend on one another and most especially, the biotic (living component) and a biotic component of the ecosystem are linked by flow on nutrients engineered by the biogeochemical cycles.

6. **Biogeochemical cycles** regulate the flow of substances. Since the biogeochemical cycles pass through different spheres, the flow of elements is regulated because each sphere has a particular medium and the rate at which elements flow is determined by the viscosity and density of the medium. Therefore, elements in the biogeochemical cycles flow at differing rates within the cycle and this regulates the flow of the elements in those cycles.

Energy Flow in the Ecosystem

Energy flows directionally through ecosystems, entering as sunlight (or inorganic molecules for chemoautotrophs) and leaving as heat during the many transfers between trophic levels. However, the matter that makes up living organisms (nutrients) is conserved and recycled. Almost all life requires the energy that flows daily from the sun. The basic conversion of this solar energy to usable form takes place through plant material on land and in water. The energy passes from plants to whatever eats them, moving up the pyramid. Energy doesn't cycle; it flows through the ecosystem until it's used up. Energy flow is closely related to the other ecosystem processes-water cycling, mineral cycling and succession. It is in fact drives these activities and makes them possible.

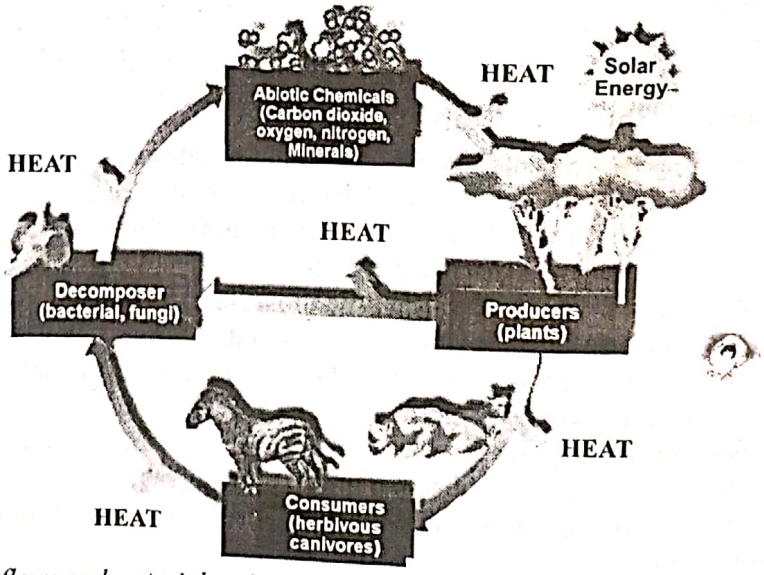


Figure 5: *Energy flows and material cycles.* (Source: Adopted from Hassani (2020)

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Energy enters the biological system as light energy, or photons, is transformed into chemical energy in organic molecules by cellular processes including photosynthesis and respiration, and ultimately is converted to heat energy. This energy is dissipated, meaning it is lost to the system as heat; once it is lost it cannot be recycled. Without the continued input of solar energy, biological systems would quickly shut down. Thus, the Earth is an ***open system*** with respect to energy (Olbers ,2012).

Elements such as carbon, nitrogen, or phosphorus enter living organisms in a variety of ways. Plants obtain elements from the surrounding atmosphere, water, or soils. Animals may also obtain elements directly from the physical environment, but usually they obtain these mainly as a consequence of consuming other organisms. These materials are transformed biochemically within the bodies of organisms, but sooner or later, due to excretion or decomposition, they are returned to an inorganic state (that is, inorganic material such as carbon, nitrogen, and phosphorus, instead of those elements being bound up in organic matter). Often bacteria complete this process, through the process called decomposition or mineralization.

During decomposition these materials are not destroyed or lost, so the Earth is a ***closed system*** with respect to elements (with the exception of a meteorite entering the system now and then. The elements are cycled endlessly between their biotic and abiotic states within ecosystems. Those elements whose supply tends to limit biological activity are called Nutrients (Olbers, 2012).

Energy Transformation

The transformations of energy in an ecosystem begin first with the input of energy from the sun. Energy from the sun is captured by the process of photosynthesis. Carbon dioxide is combined with hydrogen (derived from the splitting of water molecules) to produce carbohydrates (the shorthand notation is "CHO"). Energy is stored in the high energy bonds of adenosine triphosphate, or ATP. Plants receive the sun's energy and use it to convert inorganic compounds into rich organic compounds. Specifically, they turn sunlight and carbon dioxide into glucose and oxygen. Therefore, biological activities in an ecosystem require energy from the sun. The received solar energy undergoes an energy transformation in ecosystems into chemical energy, which is bound in glucose form as potential energy during the process of photosynthesis. This energy then flows throughout the ecosystem through the food chain and a process called energy flow.

Trophic level

The producers and consumers in ecosystem can be arranged into several feeding groups, each known as trophic level (feeding level). In any ecosystem, producers represent the first trophic level, herbivores present the second trophic level, primary carnivores represent the third trophic level and top carnivores represent the last level. In the ecosystem, green plants alone are able to trap in solar energy and convert it into chemical energy. The chemical energy is locked up in the various organic compounds, such as carbohydrates, fats and proteins, present in the green plants. Since virtually all other living organisms depend upon green plants for their energy, the efficiency of plants in any given area in capturing solar energy sets the upper limit to long-term energy flow and biological activity in the community. The food manufactured by the green plants is utilized by themselves and also by herbivores. Animals feed repeatedly. Herbivores fall prey to some carnivorous animals. In this way one form of life supports the other form. Thus, food from one trophic level reaches

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to the other trophic level and in this way a chain is established. This is known as food chain. A food chain may be defined as the transfer of energy and nutrients through a succession of organisms through repeated process of eating and being eaten. In food chain initial link is a green plant or producer which produces chemical energy available to consumers. Ideally, this transfer or flow of energy from the sun to green plants to herbivores to carnivores should be 100per cent efficient. But in reality, this does not happen, because at each link in a food chain, 80 to 90 per cent of the energy transferred is lost as heat (second law of thermodynamics). It is because of this loss that fewer individuals are found at each successive level of the food chain (e.g. fewer carnivores than herbivores). This also limits the number of levels in a food chain. This also limits the number of levels in a food chain. All organisms are part of a food chain, and may be part of more than one. Food chains usually consist of producers, primary consumers, secondary consumers, tertiary consumers and decomposers.

Every organism in an ecosystem can be assigned a feeding level, referred to as the trophic level. A trophic level consists of those organisms in food chains that are the same number of steps away from the original source of energy. Green plants would be grouped in the first trophic level(producers), herbivores in the second trophic level (primary consumers), and carnivores in the third (secondary consumers) and fourth (tertiary consumers). A number of food chains interwoven with one another give rise to a structure similar to the delicate web of a spider. These interlocking patterns formed by several food chains that are linked together are called food webs.

Food web maintains the stability of the ecosystem. The greater the number of alternative pathways the more stable is the community of living things. Most communities include various populations of producer organisms which are eaten by any number of consumer populations. The green crab, for example, is a consumer as well as a decomposer. The crab will eat dead things or living things if it can catch them. A secondary consumer may also eat any number of primary consumers or producers. This non-linear set of interactions which shows the complex flow of energy in nature is a food web in an ecosystem.

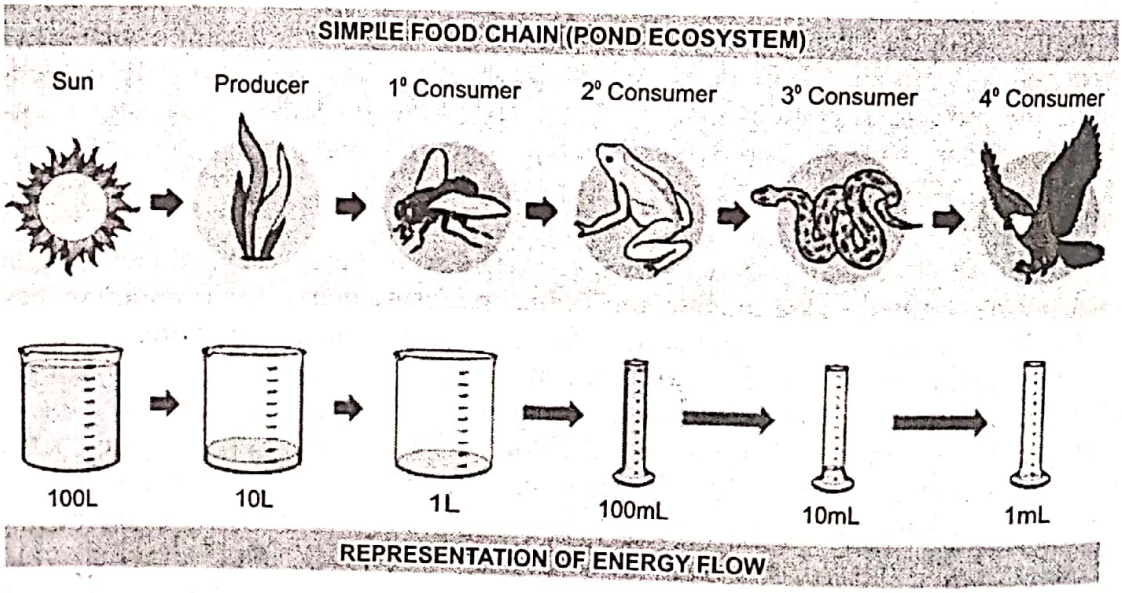


Figure 6: The Food Chain

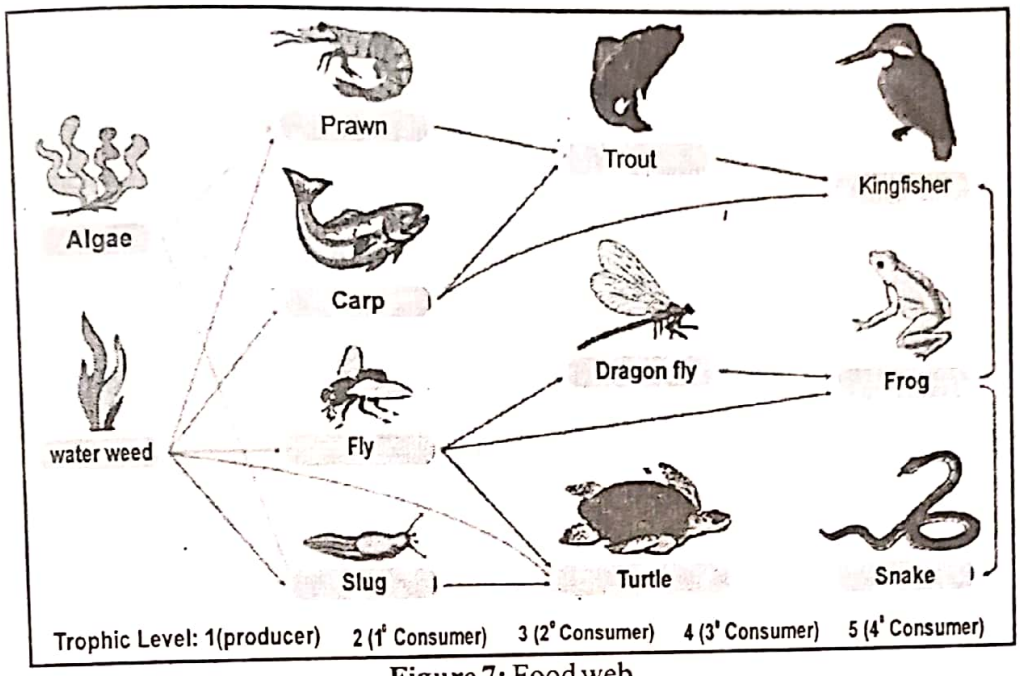


Figure 7: Food web

Ecological Pyramid

Trophic levels in a food chain can be shown graphically through ecological pyramids, with producers at the base and successive levels of consumers forming the higher layers. Ecological pyramids are of three basic types: pyramid of numbers, in which the numbers of individual organisms are depicted; pyramid of biomass, based on the total dry weight or other measures of the total amount of living matter; and pyramid of energy, in which the energy assimilated and/or productivity at successive trophic levels are shown. Ecological pyramids are used for comparing biomass and energy flow between trophic levels. Such comparisons can be used for identifying which ecosystems or communities are more efficient in terms of energy transfer.

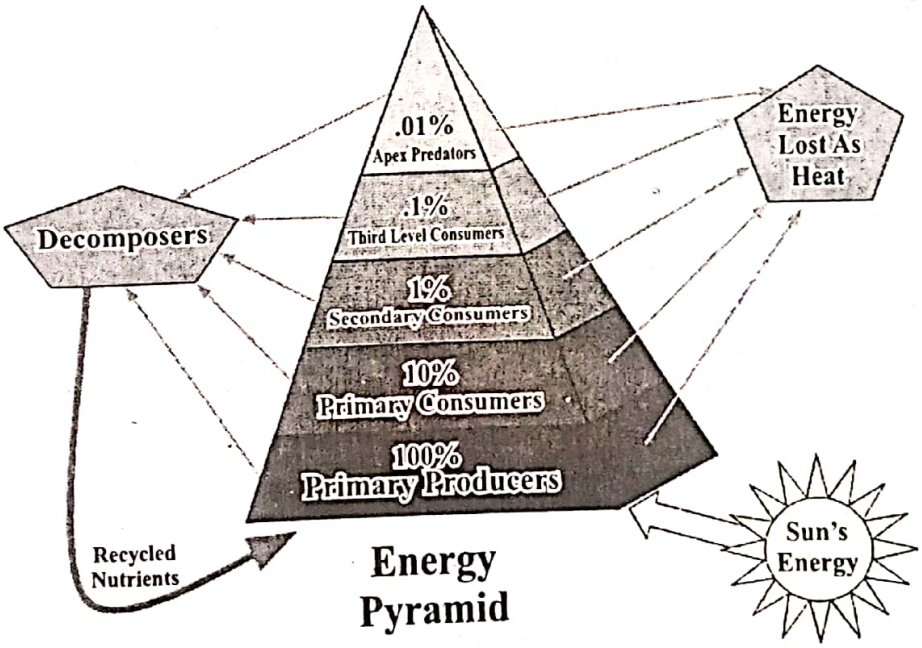


Figure 8: Ecological Pyramid

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Limitations of Energy Flow on the Ecosystem

Organisms respond to factors in the environment in which they live. These environmental factors are part abiotic (nonliving) and part biotic (living). The abiotic factors are usually the governing forces of the environment, one organism ordinarily affecting others by its ability to modify the abiotic environment. The abiotic and biotic factors function to maintain a continuous energy flow and nutrient cycling.

The abiotic limiting factors according to Muoghalu (2009) are:

a) **Temperature:** temperature is perhaps the dominating factor affecting plant and animal distribution. The arctic, the temperate zones, and the tropics are largely delimited by temperature differences. Temperature is one of the most critical factors of the environment and exerts a profound influence on all physiological activities by controlling the rate of chemical reaction. Every physiological function has temperature limits above and below which it ceases and an optimum temperature at which reactions proceed at a maximum rate. As the temperature deviates from this optimum, the rate of reaction decreases, stopping completely beyond a critical limit.

b) **Water** is required by all living things because it is critical for cellular processes. Since terrestrial organisms lose water to the environment by simple diffusion, they have evolved many adaptations to retain water. For instance, animals will be covered in an oily or waxy skin or cuticle to retain moisture. Also, plants have a number of interesting features on their leaves, such as leaf hairs and a waxy cuticle, that serve to decrease the rate of water loss via transpiration. Organisms surrounded by water are not immune to water imbalance; they too have unique adaptations to manage water inside and out of cells.

c) **Light** is essential to plants, without it, ecosystems could not function. Light also influences the reproductive and activity cycles of plants and animals. Sunlight is necessary for photosynthesis; it influences organisms and their environment; it has a profound effect on the growth and development of life.

d) **Wind** can be an important abiotic factor because it influences the rate of evaporation and transpiration. The physical force of wind is also important because it can move soil, water, or other abiotic factors, as well as an ecosystem's organisms.

e) **Fire** is another terrestrial factor that can be an important agent of disturbance in terrestrial ecosystems. Some organisms are adapted to fire and, thus, require the high heat associated with fire to complete a part of their life cycle. For example, the jack pine (*Pinus banksiana*) a coniferous tree requires heat from fire for its seed cones to open. A fire is likely to kill most vegetation, so a seedling that germinates after a fire is more likely to receive ample sunlight than one that germinates under normal conditions. Through the burning of pine needles, fire adds nitrogen to the soil and limits competition by destroying undergrowth.

f) **Inorganic Nutrients and Soil:** Inorganic nutrients, such as nitrogen and phosphorus, are important in the distribution and the abundance of living things. Plants obtain these inorganic nutrients from the soil when water moves the plant through the roots. Therefore, soil structure (particle size of soil components), soil pH, and soil nutrient content play an important role in the

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distribution of plants. Animals obtain inorganic nutrients from the food they consume. Therefore, animal distributions are related to the distribution of what they eat. In some cases, animals will follow their food resource as it moves through the environment

g) **Soil:** The type of soil, pH, amount of water it holds, available nutrients, etc. determine what type of organism can successfully live in or on the soil; for example, cacti live in sand, cattails in soil saturated with water.

The biotic limiting factors are:

1. Predators: A predator regards the organism as a source of energy and matter to be recycled.
2. A parasite is a type of consumer organism. As a consumer, it does not make its own food. It gets its food (energy and matter to be recycled) from its host.
3. The organism's prey is a source of energy and matter.
4. Symbionts: A symbiont is a factor that does not provide energy to the organism, but somehow aids the organism in obtaining energy or matter from the ecosystem.
5. Symbiosis: this describes the way in which two different species living together in the same community, interact with each other over a long time period. This can occur in the form of parasitism, mutualism or commensalism.
6. Competitors: a competitor reduces the organism's ability to harvest energy or matter to be recycled. The distribution and abundance of an organism will be affected by its interrelationships with the biotic environment.

In conclusion, the natural ecosystems of the earth are tremendously and increasingly impacted by human activities. According to Hail (2014), the difference is that agricultural, medical, and especially fossil fuel technology have allowed people to be enormously more effective at exploiting resources compared to other species, or indeed compared to our earlier selves. At the same time, the earth's ability to check our own population levels through predation and disease has been greatly reduced. The net result is that the human impact has grown enormously.

Humans have injected materials into the biosphere in large quantities that have affected the functioning of the ecosystems and have an adverse effect on life on Earth. Humans, through uncontrolled exploitation of living resources, are depleting those resources faster than nature can replace them. Because some of these factors are essential for the continued existence of life on Earth and because human activities are adversely affecting these factors thereby threatening the existence of life on Earth

We have changed the concentration of carbon dioxide in the atmosphere by only about 40% so far. If civilization continues along its present path, the change could be 500 to 1000%. Thus, natural ecosystems, and the services that they provide, are likely to continue to decrease in area and naturalness, since the human population continues to grow and most of the earth's human citizens have increasing desires for material goods, which can come only from the earth itself. Young people reading this article will almost undoubtedly see a disappearance of most of the world's natural ecosystems during their lifetimes unless there is an extraordinary effort to reduce human impact or unless that occurs involuntarily.

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