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ECOSYSTEM AND ADAPATATIONS

NEETU SINGH

The grouping or assemblage of plants, animals, and microbes we observe when we study a natural forest, grassland, pond, coral reef, or other undisturbed area is referred to as the area's **biota** (*bio*, living) or **biotic** community. Importantly, the plant portion of the biotic community includes all vegetation, from large trees down through microscopic algae. Likewise, the animal portion includes everything from large mammals, birds, reptiles, and amphibians through earthworms, tiny insects, and mites. Microbes encompass a large array of microscopic bacteria, fungi, and protozoans. Thus, one may speak of the biotic community as comprising a plant community, an animal community and a microbial community.

The particular kind of biotic community that we witness in a given area is, in large part, determined by **abiotic** (meaning non-living chemical and physical) factors, such as the amount of water or moisture present, temperature, salinity, and soil type. These abiotic conditions both support and limit the particular community. For example, a relative lack of available moisture prevents the growth of most species of plants, but supports certain species, such as cacti; we recognize such areas as deserts. Land with plenty of available moisture and suitable temperature supports forests. Obviously, the presence of water is the major factor that sustains aquatic communities.

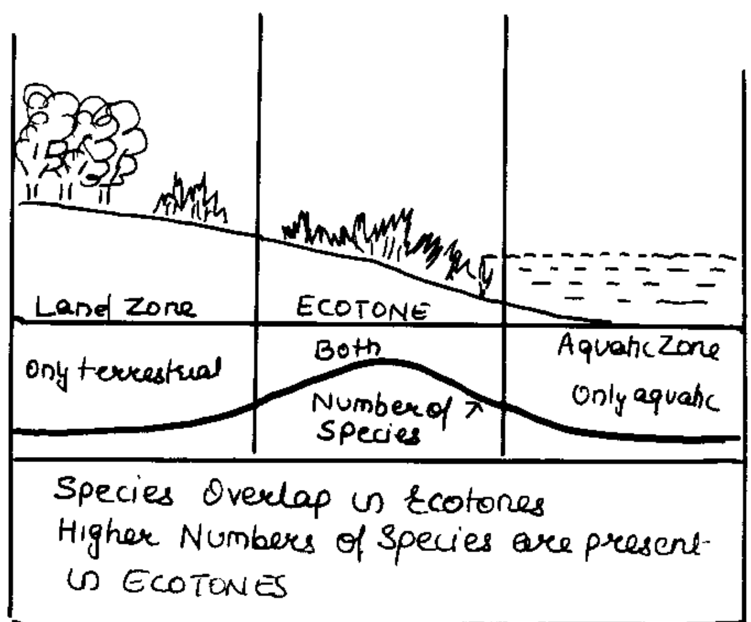
The first step in investigating a biotic community may be to simply catalogue all the species present. **Species** are the different kinds of plants, animals, and microbes. Each species includes all those individuals that have a very strong similarity in appearance to one another, and which are distinct in appearance from other such groups (Robins and Mallard ducks for example). The similarity in appearance implies a close genetic relationship. Indeed, the biological definition of a species is the entirely of a population that can interbreed and produce fertile offspring, whereas members of different species generally do not interbred or, if they do, fertile offspring are not produced. Breeding is often impractical or impossible to observe, however, so for purposes of identification the aspect of appearance suffices.

In cataloguing the species of a community, one will observe that each species is represented by a certain **population** – that is, by a certain number of individuals that make up the interbreeding, reproducing group. The distinction between population and species is that the term population is used to refer only to those individuals of a certain species that live within a given area, whereas the term species is all inclusive – it refers to all the individuals of a certain kind, even though they may exist in different populations in widely separated areas.

Continuing our study, along with the incredible variety of species and communities, it is impressive that the species within a community depend on and support one another in many ways. Most evident, certain animals will not be present unless particular plants that provide their necessary food and shelter are also present. Thus, the plant community supports (or limits by its absence) the animal community. Additionally, every plant and animal species is adapted to cope with the abiotic factors of the region. For example, every species that lives in temperate regions is adapted in one way or another to survive the winter season, which includes a period of freezing temperatures. We shall explore these interactions among organisms and their environments later. For now, the point is that the populations of different species within a biotic community are constantly interacting with each other and the abiotic environment.

This brings us to the concept of an ecosystem. An **ecosystem** is both the biotic community and the abiotic conditions in which the biotic community members live. Additionally, it includes considerations of the ways populations interact with each other and the abiotic environment to reproduce and perpetuate the entire grouping. In one sentence, an ecosystem is a grouping of plants, animals and microbes interacting with each other and with their environment in such a way as to perpetuate the grouping. For study purposes, an ecosystem may be taken to be any more or less distinctive biotic community living in a certain environment. Thus, a forest, grassland, a wetland, a marsh, a pond, a beach, and a coral reef, each with its respective species in a particular environment, can be studied as distinct ecosystems.

Since no organism can live apart from its environment or from interactions with other species, ecosystems are the functional units of sustainable life on Earth. The study of ecosystems and the interactions that occur among organisms and between organisms and their environment are the science of **ecology**, and the investigators who conduct such studies are called **ecologists**.



While it is convenient to divide the living world into different ecosystems, any investigation soon reveals that there are seldom distinct boundaries between ecosystems, and they are never totally isolated from one another. Many species will occupy (and thus be a part of) two or more ecosystems at the same time. Or, they may move from one ecosystem to another at different times, as in the case of migrating birds. In passing from one ecosystem to another, one may observe only a gradual decrease in the populations of one biotic community and an increase in the populations representing another. Thus, one ecosystem may gradate into the next through a transitional region known as an **ecotone**, which shares many of the species and characteristics of the two adjacent ecosystems.

The ecotone between adjacent systems may also include unique conditions that support distinctive plant and animal species. Consider, for example, the marshy area that often occurs between the open water of a lake and dry land. Ecotones may be studied as distinct ecosystems in their own right.

Furthermore, what happens in one ecosystem will definitely affect other ecosystems. For example, losses and fragmentation of forests have disrupted migration lanes and resulted in drastic declines in the populations of certain North American songbirds. How the loss of all these birds will affect various ecosystems is a question we cannot answer at this time.

Similar or related ecosystems are often grouped together to form major kinds of ecosystems called **biomes**. Tropical rain forests, grasslands, and deserts are examples. While more extensive than an ecosystem in its breadth and complexity, a biome is still basically a certain biotic community supported and limited by certain abiotic environmental factors. Again, there are generally no distinct boundaries between biomes, but one grades into the next through transitional regions. Indeed, there is no general agreement among ecologists as to whether certain kinds of ecosystems should be lumped within one major biomes or considered as separate biomes.

Likewise, there are a large variety of aquatic and wetland ecosystems that are determined primarily by the depth, salinity, and permanence of water. Then there are various marine (ocean) ecosystems that are determined by depth, texture of the bottom (mud vs. rock ledges), and nutrient levels, as well as by water temperature. Thus, marine ecosystems are determined more by specific environmental factors at the location than by general climatic factors, as it eh case for terrestrial biomes. Therefore, we generally speak of marine environments and not marine biomes.

Regardless of how we choose to divide (or group) and name different ecosystems, it is important to recognize that they all remain interconnected and interdependent. Terrestrial biomes are connected by the flow of rivers between them and by migrating animals. Sediments and nutrients washing from the land may nourish or pollute the ocean. Seabirds and mammals connect the oceans with the land, and all biomes share a common atmosphere and water cycle.

Therefore, all the species on Earth, along with all their environments, can be seen as one vast ecosystem, which is called the **biosphere**. Although the separate local ecosystems are the individual units of sustainability, they are all interconnected to form the biosphere. The concept is analogous to the idea that the cells of our bodies are the units of living systems, but are all interconnected to form the whole body. Carrying the analogy further, to what degree may individual ecosystems be upset or destroyed before the entire biosphere is affected.

Organization of Elements in Living and Nonliving Systems

A **molecule** refers to any two or more atoms bonded together in a specific way. The properties of a material are dependent on the specific way in which atoms are bonded to form molecules as well as on the atoms themselves. Similarly, a **compound** refers to any two or more different kinds of atoms bonded together. Note the distinction that a molecule may consist of two or more of the same kind, as well as different kinds, of atoms bonded together. A compound always implies that at least two different kinds of atoms are involved. For example, the fundamental units of oxygen gas, which consist of two oxygen atoms bonded together, are molecules but not a compound. Water, on the other hand, can be referred to as either molecules or a compound, since the fundamental units are two hydrogen atoms bonded to an oxygen atom.

The key elements in living systems (and their chemical symbols) are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), and sulfur (S). You can remember them by the acronym N. CHOPS. These six elements are the building blocks of all the organic molecules that make up the tissues of plants, animals, and microbes. We have said that growth and decay can be seen as a process of atoms moving from the environment into living things and returning to the environment. By looking at the chemical nature of air, water, and minerals, we shall see where our six key elements and others occur in the environment.

The lower atmosphere is a mixture of molecules of three important gases – oxygen (O_2), nitrogen (N_2), and carbon dioxide (CO_2) – along with trace amounts of several other gases that have no immediate biological importance. Also generally present in air are variable amounts of polluting materials and water vapour. Air is a source of carbon, oxygen, and nitrogen for all organisms.

Saying that air is a **mixture** means that there is no chemical bonding between the molecules involved. Indeed, it is this lack of connection between molecules that results in air being gaseous. Attraction, or bonding, between molecules results in liquid or solid states.

The source of the key element hydrogen is water. Each molecule of water consists of two hydrogen atoms bonded to an oxygen atom, as indicated by the formula for water: H_2O. A weak attraction between water molecules is known as hydrogen bonding. At temperatures below freezing, hydrogen bonding holds the molecules in position with respect to one another, and the result is a solid (ice or snow). At temperatures above freezing, but below vaporization (evaporation), hydrogen bonding still holds the molecules close, but allows them to move around one another, producing the liquid state. Vaporization occurs as hydrogen bonds break and water molecules move into the air independently. With a lowering of temperature all these changes in state go in the reverse direction. We reemphasize that, regardless of the changes in state, the water molecules themselves retain their basic structure of two hydrogen atoms bonded to an oxygen atom. It is only the relationship between the molecules that changes.

All the other elements required by living organisms, as well as the 72 or so elements that are not required, are found in various rock and soil minerals. A **mineral** refers to any hard, crystalline, inorganic material of a given chemical composition. Most rocks are made up of relatively small crystals of two or more minerals, and soil generally consists of particles of many different minerals. Each mineral is made up of dense clusters of two or more kinds of atoms bonded together by an attraction between positive and negative charges on the atoms.

There are simple but significant interactions between air, water, and minerals. Gases from the air and ions (charged atoms) from minerals may dissolve in water. Therefore, natural water is inevitably a solution containing variable amounts of dissolved gases and minerals. This solution is constantly subject to change, as any dissolved substances may be removed from it by various processes, or additional materials may dissolve in it. Molecules of water enter the air by evaporation and leave it by means of condensation and precipitation. Thus, the amount of moisture in air is constantly fluctuating. Wind may carry a certain amount of dust or mineral particles, and this amount is also changing constantly, since the particles gradually settle out from the air.

By contrast to the relatively simple molecules that occur in the environment (for example, CO2, H2O, N2) in living organisms we find the key atoms (C, H. O, N, P, S) bonded into very large, complex molecules known as proteins, carbohydrates(sugars and starches), lipids (fatty substances), and nucleic acids. Some of these molecules may contain millions of atoms, and their potential diversity is infinite. Indeed, the diversity of living things is a reflection of the diversity of such molecules.

The molecules that make up the tissues of living things are constructed mainly from carbon atoms bonded together into chains with hydrogen atoms attached. Oxygen, nitrogen, phosphorus, and sulfur may be present also, but the key common denominator is carbon-carbon and/or carbon-hydrogen bonds. Material making up the tissues of living organisms is referred to as organic. Hence, these carbon-based molecules, which make up the tissues of living organisms, are called **organic molecules**. **Inorganic**, then, refers to molecules or compounds with neither carbon-carbon nor carbon-hydrogen bonds.

Causing some confusion is the fact that all plastics and countless other human-made compounds are based on carbon-carbon bonding and are, chemically speaking, organic compounds – although they have nothing to do with living systems. Where there is doubt, we resolve this confusion by referring to the compounds of living organisms as **natural organic compounds** and the human-made ones as **synthetic organic compounds**.

In conclusion, we can see that the elements essential to life (C, H, O, and so on) are present in air, water, or minerals in relatively simple molecules. In living organisms, on the other hand, they are organized into very complex organic molecules. These organic compound sin turn make u the various parts of cells, which make up the tissues and organs of the body. Growth, then, may be seen as using the atoms from simple molecules in the environment to construct the complex organic molecules of an organism. Decomposition and decay may be seen as the reverse process.

Energy Considerations

In addition to the rearrangement of atoms, chemical reactions also involve the absorption or release of energy. To grasp this context, let us examine the distinction between matter and energy.

Matter and Energy – The universe is made up of matter and energy. A more technical definition of **matter** is anything that occupies space and has mass – that is, can be weighted when gravity is present. This definition obviously covers all solids, liquids, and gases, and living as well as nonliving things.

Atoms are made up of protons, neutrons, and electrons, which in turn are made of still smaller particles. Thus physicists debate what the most basic units of matter is. However, since atoms are the basic units of all elements and remain unchanged during chemical reactions, it is practical to consider them as the basic units of matter.

Light, heat, movement and electricity, on the other hand, do not have mass, nor do they occupy space. (Note that heat, as used here, refers not to a hot object but to the heat energy we can feel radiating from the hot object). These are the common forms of energy which we experience continually – or perhaps their lack is a more significant experience. What do forms of energy have in common? They affect matter, causing changes in its position or its state. For example, the release of energy in an explosion causes things to go flying, a change in position. Heating water causes it to boil and change to steam, a change in state. On a molecular level, changes in state may be seen as movements of atoms or molecules. For example, the degree of heat energy is actually a measure of the relative vibrational motion of the atoms and molecules of the substance. Therefore, **energy** is the ability to move matter.

Energy is commonly divided into two major categories: kinetic and potential. **Kinetic energy** is energy in action or motion. Light, heat energy, physical motion, and electrical current are all forms of kinetic energy. **Potential energy** is energy in storage. A substance or system with potential energy has the capacity, or potential, to release one or more forms of kinetic energy. A stretched rubber band, for example, has potential energy; it can send a paper clip flying. Numerous chemicals, such as gasoline and other fuels, release kinetic energy – heat energy, light, and movement – when ignited. The potential energy contained in such chemicals and fuels is called **chemical energy**.

Energy may be changed from one form to another in innumerable ways. Besides seeing that potential energy may be converted to kinetic energy, it is especially important to recognize that kinetic energy may be converted to potential energy, as in changing a battery or pumping water into a high elevation reservoir. We shall see shortly that photosynthesis is another such process.

Because energy does not have mass or occupy space, it cannot be measured in units of weight or volume, but it can be measured in other kinds of units. One of the most common units is the **calorie**, which is defined as the amount of heat, required to raise the temperature of 1 gram (1 milliliter) of water 1 degree Celsius. Since this is a very small unit, it is frequently more convenient to speak in terms of kilocalories (1 kilocalorie = 1,000 calories), the amount of heat required to raise 1 liter (1000 milliliters) of water 1 degree Celsius. Kilocalories are sometimes denoted as ‘Calories’ with a capital ‘C’. Food Calories, which are a measure of how much energy our bodies can derive from given foods, are actually kilocalories. Any form of energy can be measured in calories by converting it to heat energy and measuring that heat in terms of a rise in the temperature of water. Temperature is a measurement of the molecular motion in a substance caused by the kinetic energy present.

We define energy as the ability to move matter. Conversely, no change in the movement of matter can occur without the absorption or release of energy. Indeed, no change in matter – from a few atoms joining together or coming apart in a chemical reaction to a major volcanic eruption – can be separated from respective changes in energy.

Energy Laws: Laws of Thermodynamics – Knowing that energy can be converted from one form to another has led numerous would-be inventors over the years to try to build machines or devices that would produce more energy than they consumed. A common idea that occurs to many students is to use the output from a generator to drive a motor that, in turn, drives the generator to keep the cycle going and yields additional power in the bargain. Unfortunately, all such devices have one feature in common: They don’t work. When all the inputs and outputs of energy are carefully measured, they are found to be equal. There is no net gain or loss in total energy. This observation is now accepted as a fundamental natural, the **law of conservation of energy**, also called the **first law of thermodynamics**: Energy is neither created nor destroyed, but may be converted from one form to another. The law is also commonly stated as ‘You can’t get something for nothing’.

Fanciful ‘energy generators’ fail for two reasons. First, in every energy conversion, a portion of the energy is converted to heat energy (thermal infrared). Second, heat always flows toward cooler surroundings. There is no way of trapping and recycling heat energy, since it can flow only ‘downhill’ toward a cooler place. Consequently, in the absence of energy inputs, any and every system will sooner or later come to a stop as the energy is converted to heat and lost. This is now accepted as another natural law, the **second law of thermodynamics**. Basically, the second law says that, in any energy conversion, you will end up with less usable energy than you started with. So, not only can you not get something for nothing (the first law), you can’t even break even.

A principle that underlies the loss of heat is the principle of increasing entropy. **Entropy** refers to the degree of disorder: Increasing entropy means increasing disorder. The principle is that, without energy inputs, everything goes in one direction only, toward increasing entropy. This principle of ever-increasing entropy is most readily apparent in the fact that all human-made things tend to deteriorate. We never observe the reverse – a run-down building renovating itself, for example. Students often like to speak of the increasing disorder of their dormitory rooms as the semester wears on as an example of entropy.

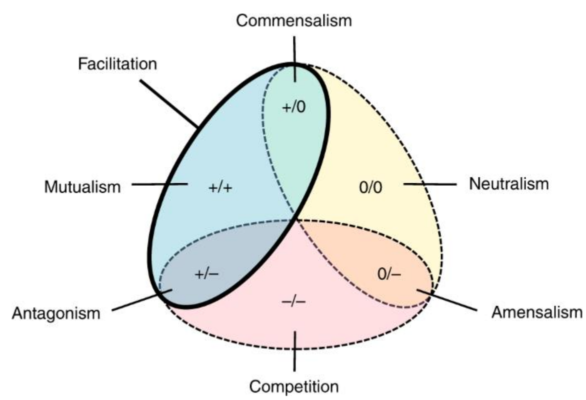
The conversion of energy and the loss of heat are both aspects of increasing entropy. Heat energy is the result of the random vibrational motion of atoms and molecules. Thus, it is the lowest (most disordered) form of energy, and its flow to cooler surroundings is a way for that disorder to spread. Therefore, the second law of thermodynamics is nowadays more generally stated as: Systems will go spontaneously in one direction only; toward increasing entropy. The second law also says that systems will go spontaneously only toward lower potential energy, a direction that releases heat from the systems.

Very important in the statement of the second law is the word spontaneously. It is possible to pump water uphill, charge a battery, stretch a rubber band, compress air, or otherwise increase the potential energy of some system. However, inherent in such words as pump, charge, stretch, and compress is the fact that energy is being put into the system; in contrast, the opposite direction, which releases energy, occurs spontaneously.

The conclusion is that whenever you see something gaining potential energy, you should realize that energy is being obtained from somewhere else (the first law). Moreover, the amount of energy lost from that somewhere else is greater than the amount gained (the second law). Let us now relate these concepts of matter and energy to organic molecules, organisms, ecosystems , and the biosphere.

Population Interactions

Non-feeding Relationships: Mutually Supportive Relationships – The overall structure of ecosystems is dominated by feeding relationships, as we have just seen. In any feeding relationship, we generally think of one species benefiting and the other being harmed to a greater or lesser extent. However, there are many relationships that provide a mutual benefit to both species. This phenomenon is called **mutualism**. A common example is the relationship between flowers and insects: The insects benefit by obtaining nectar from the flowers, and the plants benefit by being pollinated in the process. Another example is observed in tropical seas; Clownfish are immune to the toxin in the tentacles of sea anemones, which the anemones use to immobilize their prey. Thus, these fish are able to feed on detritus around the anemones, at the same time receiving protection from would-be predators that are not immune. The anemones benefit by being cleaned.



In some cases, the mutualistic relationship has become so close that the species involved are no longer capable of living alone. A classic example is the group of plants known as ***lichens***. A lichen actually comprises two organisms: a fungus and an alga. The fungus provides protection for the alga, enabling it to survive in dry habitats where it could not live by itself, and the alga, which is a producer, provides food for the fungus, which is a heterotroph. Two species living together in close union are said to have a symbiotic relationship. However, **symbiosis** by itself simply refers to the fact of 'living together' in close union (*sym*, together; *bio*, living); it does not specify a mutual benefit or harm. Therefore symbiotic relationships may include parasitic relationship as well as mutualistic relationships.

While not categorized as mutualistic, countless relationships in an ecosystem may be seen as aiding its overall sustainability. For example plant detritus provides most of the food for decomposers and soil-dwelling detritus feeders such as earthworms. Thus, these organisms benefit from plants, but the plants also benefit because the activity of the organisms is instrumental in releasing nutrients from the detritus and in returning them to the soil where they can be reused by the plants. In another example, insect-eating birds benefit from vegetation by finding nesting materials and places among trees, while the plant community benefits because the birds feed on and reduce the populations of many herbivorous insects. Even in predator-prey relationships, some mutual advantage may exist. The killing of individual prey that is weak or diseased may benefit the population at large by keeping it healthy. Predators and parasites may also prevent herbivore populations from becoming so abundant that they overgraze their environment.

Competitive Relationships – Given the concept of food webs, it might seem that species of animals would be in a great 'free-for-all' competition with each other. In fact, fierce competition rarely occurs, because each species tends to be specialized and adapt3ed to its own habitat and/or niche.

Habitat refers to the kind of place – defined by the plant community and the physical environment – where a species is biologically adapted to live. For example, a deciduous forest, a swamp, and an open grassy field denote types of habitats. Types of forests (e.g. conifer vs. deciduous) provide markedly different habitats and support a variety of wildlife.

Even when different species occupy the same habitat, competition may be slight or nonexistent, for the most part, because each species has its own niche. An animal's **niche** refers to what it feeds on, where it feed, when it feeds, where it finds shelter, and where it nests. Seeming competitors can coexist in the same habitat but have separate niches. For example, woodpeckers, which feed on insects in dead wood, are not in competition with birds that feed on seeds. Many species of songbirds coexist in forests because they feed on insects from distinct levels in the trees. Bats and swallows both feed on flying insects, but they are not in competition, because bats feed at night and swallows feed during the day.

There is often interspecies competition where different habitats or niches overlap. If two species do compete directly in every respect, as sometimes occurs when a species is introduced from another continent, one of the two generally perishes in the competition – this is the ***competitive exclusion principle (Gausse principle)***.

All green plants require water, nutrients, and light, and where they are growing in the same location; one species may eliminate others through competition. (Hence, maintaining flowers and vegetables against the advance of weeds is a constant struggle). However different plant species are also adapted and specialized to particular conditions. Thus, each species is able to hold its own against competition where conditions are well suited to it. The same concepts hold true for species in aquatic and marine ecosystems.

Ecosystem Balance is Population Balance

Each species in an ecosystem exists as a population – that is to say, a reproducing group. For an ecosystem to remain stable (to retain the same mix of populations of different species) over a long period of time, the population of each species in the ecosystem must remain more or less constant in size and geographic distribution. In short, on average deaths must equal births; otherwise the population would shrink or grow accordingly. We speak of an equilibrium between births and deaths as **population balance**. In turn, ecosystems sustainability or balance boils down to a problem of how population is maintained for all the species that comprise the ecosystem.

Biotic Potential versus Environmental Resistance

First among the factors for increasing population size is **biotic potential**, the number of offspring (live births, eggs laid, or seeds or spores set in plants) that a species may produce under ideal conditions. Looking at different species you can readily see that biotic potential varies tremendously, averaging from less than one birth per year in certain mammals and birds to many millions per year in the case of many plants, invertebrates, and fish. However, to have any effect on the size of subsequent generations, the young must survive and reproduce in turn. Survival through the early growth stages to become part of the breeding population is called **recruitment**. Recruitment is the second factor in population growth.

Considering differences in biotic potential and recruitment, you can see two different **reproductive strategies**. The first strategy is to produce massive numbers of young, but then leave survival to the whims of nature. This strategy results in very low recruitment. Thus, despite high biotic potential, population increase may be nil because recruitment is so low. (Note that 'low recruitment' is a euphemism for high mortality of the young). The second strategy is to have a much lower reproductive rate, but then provide care and protection to the young so as to enhance recruitment.

Additional factors that influence population growth and geographic distribution are the ability of animals to migrate or of seeds to disperse, to similar habitats in other regions; the ability to adapt to and invade new habitats; defense mechanisms; and resistance to adverse conditions and to disease.

Taking all these factors for population growth together, we find that every species has the capacity to increase its population when conditions are ideal. Furthermore, growth of a population under ideal conditions will be exponential. Such a series is called an **exponential increase**. When this occurs in a population, it is commonly called a **population explosion**. A basic feature of such an exponential increase is that the numbers increase faster and faster as the population doubles and redoubles, with each doubling occurring in the same amount of time.

Population explosions are seldom seen in natural ecosystems, however, because a large number of both biotic and abiotic factors tends to decrease population. Among the biotic factors are predators, parasites, competitors, and lack of food. Among abiotic factors are unsuitable temperature, moisture, light, salinity, pH, and lack of nutrients. The combination of all the abiotic and biotic factors that may limit population increase is referred to as **environmental resistance.**

You may already foresee the result of the interplay between the factors promoting population growth and those leading to population decline. Conditions are always changing. When they are favourable, populations may increase. When they are unfavourable, populations decrease.

In general, the reproductive rate of a species remains fairly constant, because that rate is part of the genetic endowment of the species. What varies substantially is recruitment. It is in the early stages of growth that individuals (plants or animals) are most vulnerable to predation, disease, lack of food (or nutrients) or water, and other adverse conditions. Consequently, environmental resistance effectively reduces recruitment. Of course, some adults also perish, particularly the old or weak. If recruitment is at the **replacement level**, that is, just enough to replace these adults, then the size of the population will remain constant. If recruitment is not sufficient to replace losses in the breeding population, at that point, the size of the population will decline.

In certain situations, environmental resistance may affect reproduction as well as causing mortality directly. For example, the loss of suitable habitat often prevents animals from breeding. Also, certain pollutants adversely affect reproduction. However, we can still view these situations as environmental resistance that either blocks a population's growth or causes its decline.

In sum, whether a population grows, remains stable, or decreases is the result of an interplay between its biotic potential and environmental resistance. In general, biotic potential remains constant; it is shifts in environmental resistance that allow populations to increase or cause them to decrease. For example, a number of favourable years (low environmental resistance) will allow a population to increase; then a drought or other unfavourable conditions may cause it to die back, and the cycle may be repeated.

We emphasize that population balance is a **dynamic balance**, which implies that additions (births) and subtractions (deaths) are occurring continually and the population may fluctuate around a median. Some fluctuate very little; others fluctuate widely, but as long as decreased populations restore their numbers, the system may be said to be balanced. Still, the questions remain: What maintains the balance within a certain range? What prevents a population from 'exploding' or, conversely, becoming extinct? Indeed, as balances are upset, these events can and do occur.

Density Dependence and Critical Numbers

In general, the size of a population remains within a certain range because most factors of environmental resistance are density dependent. That is, as **population density** (the number of individuals per unit area) increases, environmental resistance becomes more intense and causes such an increase in mortality that population growth ceases or declines. Conversely, as population density decreases, environmental resistance is generally mitigated, allowing the population to recover.

But again, there are no guarantees that a population will recover from low numbers. Extinctions can and do occur in nature. For example, where are the dinosaurs? The survival and recovery of a population depends on a certain minimum population base, which is referred to as the **critical number**. You can see the idea of critical number at work in terms of a herd of deer, a pack of wolves, a flock of birds, or a school of fish. Often, the group is necessary to provide protection and support for its members. In some cases, the critical number is larger than a single pack or flock, because interactions between groups may be necessary as well. In any case, if a population is depleted to below the critical number needed to provide such supporting interactions, the surviving members actually become more vulnerable, breeding fails, and extinction is virtually inevitable. Thus, we must recognize that the density-dependent decline and recovery of a population occurs well above the critical number for the population.

Why are human activities causing so many extinctions? It is simply that human impacts, such as alterating habitats, pollution, hunting, and other forms of exploitation are not density dependent; they can even intensify as populations decline toward extinction.

Environmentalism represents an attempt to create a new kind of balance through using acquired wisdom and intelligence. Scientists are monitoring many populations. Species whose populations are declining rapidly because of human impacts are classified as **threatened**. If the population is near what scientists believe to be its critical number, the species may be classified as **endangered**. These definitions, when officially assigned by the U.S. Fish and Wildlife Service, set into motion a number of actions aimed at stemming the negative impacts on, and providing protection for and even artificial breeding of, the species in question. Nongovernmental organizations, such as the World Wildlife Fund, are also playing a great role in protecting threatened and endangered species.

Mechanisms of Population Balance

With our general understanding of population balance as a dynamic interplay between biotic potential and environmental resistance, we now turn our attention to some specific kinds of population-balancing interactions. (Keep in mind, however, that in the natural world a population is subjected to the total array of all the biotic and abiotic environmental factors around it. Single factors are seldom totally responsible for the regulation of a given population; rather, regulation results from many factors acting together).

Predator-Prey and Host-Parasite Balances

The best known mechanism of population balance is regulation of a population by a predator, that is, a predator-prey balance.Ecologists generally agree that the rise and fall of the predator population is in response to the availability of prey. But there is debate as to whether the predator is the primary or only cause of the leveling and decline of the prey population. Other factors are generally involved as well. For example, the shortage of vegetation that occurs as the herbivore population grows may stress the animals, especially the old, sick, and young, and make them more vulnerable to predation. The observation that predators are incapable of killing individuals of their prey that are mature and in good physical condition is extremely significant. This is what puts the brakes on a predator eliminating its prey. As the prey population is culled down to those healthy individuals that can escape attack, the predator population has no choice but to starve back to a lower level. Meanwhile, the survivors of the prey population are the most healthy of the stock and can readily procreate the next generation.

Much more abundant and ecologically important than predators in population control are a huge diversity of parasitic organisms. These organisms range from tapeworms, which may be a foot or more in length, to microscopic disease-causing protozoans, fungi, bacteria, and viruses. All species of plants and animals, and even microbes themselves, may be infected with parasites.

In terms of population balance, parasitic organisms act in the same way as large predators do. As the population density of the host organism increases, parasites and their vectors (agents that carry the parasites from one host another), such as disease-carrying insects, have little trouble finding new hosts, and infection rates increase, causing die-off. Conversely, when the population density of the host is low, transfer of infection is impeded, and there is a great reduction in levels of infection, a condition that allows the population to recover.

You can readily see how a parasite can work in conjunction with a large predator in the control of a give herbivore population. Parasitic infection breaks out in a dense population. Individuals weakened by infection are readily removed by predators, leaving a smaller but healthier population.

In a food web, a population of any given organisms is affected by a number of predators and parasites simultaneously. Consequently, the balance among them can be thought of more broadly as a balance between the population of an organism and its **natural enemies**.

Balances between an organism and several natural enemies are generally much more stable and less prone to wide fluctuations than when only a single natural enemy is involved, because different natural enemies come into play at different population densities. Also, when the preferred prey is at a low density, the population of the natural enemy may be supported by its feeding on something else. Thus, the lag time between an increase in the prey population and that of the natural enemy is diminished. These factors have a great damping effect on the rise and fall of the prey population. The wide swings observed in the populations of moose and wolves on Isle Royale are seen to occur in very simple ecosystems involving relatively few species.

Territoriality

Territoriality refers to individuals or groups such as a pack of wolves defending a territory against the encroachment of others of the same species. For example, the males of many species of songbirds claim a territory at the time of nesting. Their song has the function of warning other males to keep away. The males of many carnivorous mammals, including dogs, ‘stake out’ a territory by spotting it with urine, the smell of which warns others to stay away. If there is encroachment, there may be a fight, but in natural species a large part of the battle is intimidation – an actual fight rarely results in death.

In territoriality what is really being defended, or sought after by the ‘invader’ is the claim to an area from which adequate food resources can be obtained in order to rear a brood successfully. Hence the territory is only defended against others that would cause a direct competition for those resources. As a consequence of territoriality some members of the population are able to gain access to sufficient food resources to rear a well-fed next generation. Thus, a healthy population of the species survives. If, instead, there were an even rationing of inadequate resources to all the members, all of them trying to raise broods, the entire population would become malnourished and might perish. By territoriality, breeding is restricted to only those individuals that are capable of claiming and defending territory, and thus population growth is curtailed.

Individuals unable to claim a territory are in large part the young of the previous generation(s). Some may hang out on the fringes and seize their opportunity as they become more mature, and older members with territories weaken. Some fall prey to one or another factors of environmental resistance as they are continually chased out of one territory after another. Finally, some may be driven to migrate. Of course, it is an open question whether such migration will lead them to another region where they can successfully breed, or whether it will lead them to perish in conditions beyond their limit of tolerance along the way. In any case, territoriality may be seen as a powerful force behind migration as well as population stabilization.

Plant-Herbivore Balance

We observed that herbivore populations are commonly held in check by various natural enemies. In turn, keeping the herbivore population in check prevents it from growing to the extent that overgrazing occurs.

The lesson is that no population can escape ultimate limitation by environmental resistance. But the form of environmental resistance and the consequences may differ. If a population is not held in a reasonable balance, it may explode, overgraze, and then crash as a result of starvation. It is also crucial to note that the consequence is not just to the herbivore in question. One or more types of vegetation may be eliminated and replaced by other forms or not replaced at all, leaving a ‘desert’. Other herbivores that were dependent on the original vegetation, and secondary and higher levels of consumers dependent on them, also are eliminated as food chains are severed. Innumerable extinctions have occurred among the unique flora and fauna of islands because goats were introduced by sailors to create a convenient food supply for return trips.

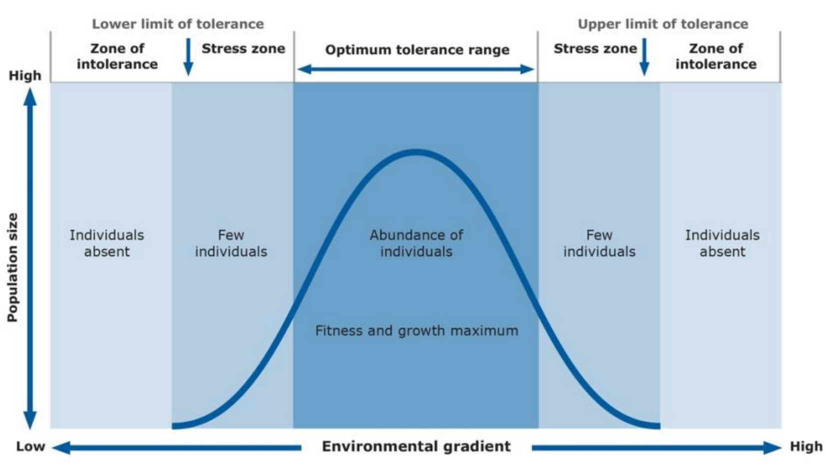
Eliminating predators or other natural enemies upsets basic plant-herbivore balances in the same way as introducing an animal without natural enemies does. Examples of this type of folly abound as well. For example, in much of the United States, deer populations were originally controlled by wolves, mountain lions, and black bear, most of which have been killed because there were felt to be a threat to livestock and even humans. Now, were it not for human hunting in place of these natural predators, deer populations in most areas would increase to the point of overgrazing. Indeed, drastic population increases do occur where hunting is prevented. Similarly, prairie dogs and other small rodents are becoming an increasing problem in the western United States as a result of a reduction in the number of their predators, such as coyotes. In this case, hunting is obviously not practical – who wants to go hunting for mice?

A second factor influencing plant-herbivore balance is that large herbivores – bison in the American West or elephants in Africa, for example – were originally able to roam vast regions. As forage was reduced in one area, a herd would simply move on before overgrazing could occur. Because humans have fenced such regions for agriculture and cattle ranching, however, wild herbivores are increasingly confined to areas such as parks and reserves. Overgrazing in such presumably ‘protected’ areas is become an increasing danger.

Carrying Capacity

The preceding examples lay open another basic concept. There is a definite upper limit to the population of any particular animal that an ecosystem can support without being upset and degraded. This limit is known as the carrying capacity. More precisely, **carrying capacity** is defined as the maximum population of an animal that a given habitat will support without the habitat being degraded over the long term. The concept of carrying capacity is being given more and more consideration by wildlife managers. Also, many are asking, What is the carrying capacity of the biosphere for humans? Unfortunately, carrying capacity is subject to many variables – especially when the subject is humans – and is not easy to determine.

To this point, our discussion has focused on large grazing animals, but such animals are really a small fraction of the total biota. It is significant to observe that plants are attacked by an incredible variety of insects and other arthropods; these, in turn, both support and are controlled by a vast variety of arthropod-eating organism, including carnivorous insects, spiders, birds, amphibians, reptiles, and some mammals, such as bats and tree mice.



Balances among Competing Plants

A natural ecosystem may contain hundreds or even thousands of species of green plants, all competing for nutrients, water, and light. How is the balance among competing plants maintained? What prevents one plant species from driving out others in competition – again, an event they may occur in the case of introduced species?

First, we observed that, because of differences in topography, soil type, and so on, the environment is far from uniform. It is actually comprised of numerous microclimates or microhabitats. That is to say, the specific conditions of moisture, temperature, light, and so on differ from location to location. Thus, the adaptation of a species to specific conditions enables it to thrive and overcome its competitors in one location but not in another. An example is the distribution of trees along streams and rivers. In the Great Plains states, trees only grow along waterways, because elsewhere the environment is too dry. This creates what are called **riparian** woodlands. In the eastern United States sycamore and/or cedar, which can thrive in water-saturated soil, grow along river banks. Oaks, which require well-drained soil, occupy higher elevations. In the West, white alder, willow, and cottonwoods can survive in water saturated soils.

A second factor affecting the balance among competing plant species is the fact that a single species generally cannot utilize all of the resources in a given area. Therefore, any resources that remain may be gathered by other species having different adaptations. For example, grasslands contain both grasses, which have a fibrous root system, and plants that have tap roots. These different root systems enable the plants to coexist because they get their water and nutrients from different layers of the soil. Also, trees in a forest, while competing with each other for light in the canopy (the layer of treetops), leave lots of space near the ground, and this space may be occupied by plants (ferns and mosses, for example) that can tolerate the reduced light intensity. Another adaptation is the plethora of spring wild flowers that inhabit temperate deciduous forests. Sprouting from perennial roots or bulbs in the early part of that season, these plants take advantage of the light that can reach the forest floor before the trees grow leaves. In warm, humid climates, the branches of trees are often covered with **epiphytes**, or air plants. Such plants are not parasitic; indeed there may be mutualistic symbiosis involved. There is some evidence that the epiphytes help to gather the minute amounts of nutrients that come with rainfall (e.g. nitrogen compounds fixed by lightning) and make them accessible to the tree on which the epiphytes are located.

A third and very important factor in multiple-plant balance is called balanced herbivory. It is easiest to understand if we start from the point of view of a **monoculture** – the growth of a single species over a wide area, a practice commonly followed in agriculture and forestry for economic efficiency.

Experience shows that monocultures are exceedingly vulnerable to insects, fungal diseases, or other pests, while diverse ecosystems are much more resistant to them. To understand why this should be, consider the following. First, insects, fungal diseases, and other parasites are, for the most part, **host specific**. That is, they will attack only one species and, possibly, its close relatives. They are unable to attack species unrelated to their specific host. Second, such organisms have an enormous biotic potential. An individual often produces thousands of offspring – even millions in the case of fungal spores – and they have a generation time of only a few days or weeks.

Now, a monoculture may be seen as a continuous, lush food supply for its particular host-specific attacker, a situation highly conducive to supporting a population explosion. Indeed, the pest population may explode so fast that its natural enemies cannot keep up with it even if they are present. Only virtual elimination of the monoculture halts the multiplication of the pest – a scenario not unlike that of the reindeer described earlier. (It is for this reason that many farmers and forest managers feel obliges to use chemical pest controls despite recognizing that they may present certain environmental hazards).

On the other hand, in a diverse ecosystem – one consisting of a mixture of many different species of plants growing together – the host-specific attacker has trouble reaching its next host. With this limitation, most of the pest's offspring may perish, and the surviving population may be held in check by its natural enemies.

To conclude, visualize a monoculture developing in a natural situation. Its being largely wiped out by an outbreak of its host-specific pest would leave space that might be invaded by another plant species, which in turn might be largely wiped out by an outbreak of its pest, leaving space that might be occupied by a third plant species, and so on. The end result of this process would be a diversified plant community, with each species held to a low density by its specific herbivore(s) and the herbivores held in check by their natural enemies. Thus, a **balanced herbivory** may be defined as a balance among competing plant populations being maintained by herbivores feeding on the respective populations.

A prime example of a balanced herbivory is seen in the tropical rain forests of the Amazon River basin in Brazil and Peru. A single acre may contain a hundred or more species of trees, but often no more than a single individual of each. The next individual of the same species may be as much as a half as a half mile away. Evidence that this diversity is maintained by a balanced herbivory is seen in that attempts to create plantations of single species – rubber plantations, for example – met with failure because outbreaks of various pests proved uncontrollable in the monoculture situation. (However, rubber plantations proved successful in Malaysia, where climatic and soil conditions are different enough to limit pests while still supporting the rubber trees).

The balance among competing plant species may also be upset by the introduction of an herbivore, which invariably attacks some plant species but not others. For example, millions of acres of pasture and range lands are now dominated by inedible weeds and shrubs as cattle have eaten back the grass and allowed the competing weeds to flourish.

The Structure of Ecosystems

Structure refers to parts and the way they fit together to make the whole. There are two key aspects to every ecosystem: the biota or biotic community and the abiotic environmental factors. The way different categories of organisms fit together is referred to as the **biotic structure**.

Biotic Structure

Despite the diversity of ecosystems, all have a similar biotic structure, based on feeding relationships. That is, all ecosystems have the same three basic categories of organisms that interact in the same ways.

Categories of Organisms – The major categories of organisms are (1) producers, (2) consumers, and (3) detritus feeders and decomposers. Together, these groups produce food, pass it along food chains and return the starting materials to the abiotic parts of the environment.

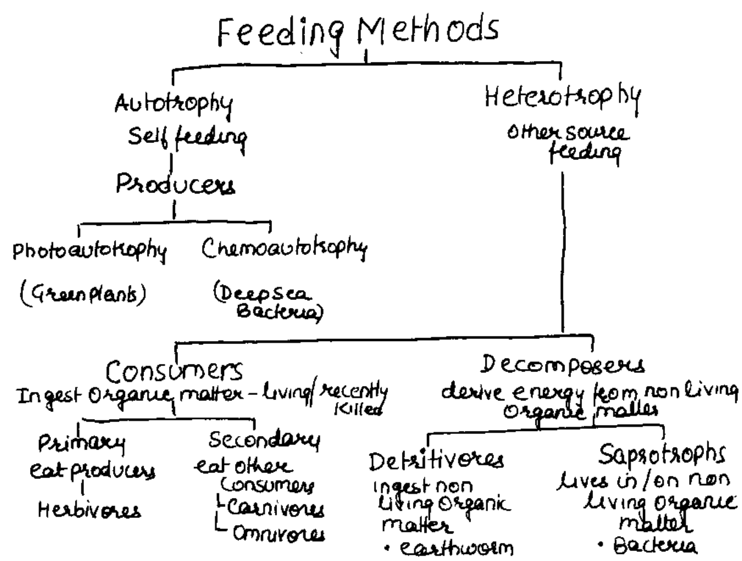
Producers: Producers are mainly green plants, which use light energy from the Sun to convert carbon dioxide (absorbed from air or water) and water to a sugar called glucose and release oxygen as a by-product. This chemical conversion, which is driven by light energy, is called **photosynthesis**. Plants are able to manufacture all the complex molecules that make up their bodies from the glucose produced in photosynthesis, plus a few additional mineral nutrients such as nitrogen, phosphorus, potassium, and sulfur, which they absorb from the soil or from water.

The molecule that plants use to capture light energy for photosynthesis is **chlorophyll**, a green pigment. Hence, plants that carry on photosynthesis are easily identified by their green colour. (In some cases, the green may be overshadowed by additional red or brown pigments. Thus, red algae and brown algae also carry on photosynthesis.) Producers range in diversity from microscopic, single-celled algae through medium-sized plants such as grass, daisies, and cacti to gigantic trees. Every major ecosystem, both aquatic and terrestrial, has its particular producers carrying on photosynthesis.

The term **organic** is used to refer to all those materials that make up the bodies of living organisms – molecules such as proteins, fats or lipids, and carbohydrates. Likewise, materials that are specific products of living organisms, such as dead leaves, leather, sugar, and wood, are considered organic. On the other hand, materials and chemicals of air, water, rocks and minerals, which exist apart from the activity of living organisms, are considered **inorganic**. The key feature of organic materials and molecules is that they are in large part constructed from bonded carbon and hydrogen atoms, a structure that is not found among inorganic materials. This carbon-hydrogen structure has its origin in the process of photosynthesis. Hydrogen atoms taken from water molecules and carbon atoms from carbon dioxide are joined together to form organic compounds in the process of photosynthesis. Green plants use light as the energy source to produce all the complex organic molecules their bodies need from the simple inorganic chemicals (carbon dioxide, water, mineral nutrients) present in the environment. As this conversion from inorganic to organic occurs, some of the energy from light is stored in the organic compounds.

Now, all organisms in the ecosystem other than green plants feed on organic matter as their source of both energy and nutrients. These include not only all animals, but also **fungi** (mushrooms, molds, and similar organisms), most bacteria, and even a few higher plants, such as Indian pipe, that do not have chlorophyll and that therefore cannot carry on photosynthesis.

Thus, green plants, which carry on photosynthesis, are absolutely essential to every ecosystem. Their photosynthesis and growth constitute the production of organic matter, which sustains all other organisms in the ecosystem.



Indeed, all organisms in the biosphere can be divided into two categories, autotrophs and heterotrophs, on the basis of whether they do or do not produce the organic compounds they need to survive and grow. Those organisms such as green plants, which produce their own organic material from inorganic constituents in the environment using an external energy source, are **autotrophs** (*auto*, self: *troph*, feeding). As previously mentioned, the most important and common autotrophs by far are green plants, which use chlorophyll to capture light energy for photosynthesis. However, a few bacteria use a purple pigment for photosynthesis, and some other bacteria acquire their energy from certain high-energy inorganic chemicals. All other organisms, however, which must consume organic material to obtain energy and nutrients, are **heterotrophs** (*hetero*, other). Heterotrophs may be divided into numerous subcategories, the two major categories being **consumers** (which eat living prey), and **detritus feeders** and **decomposers** both of which feed on dead organisms or their products.

Consumers – Consumers encompass a wide variety of organisms ranging in size from microscopic bacteria to blue whales and include such diverse groups as protozoans, worms, fish and shellfish, insects, reptiles, amphibians, birds, and mammals (including humans).

For the purpose of understanding ecosystem structure, consumers are divided into various subgroups according to their food source. Animals, be they as large as elephants or as small as mites, that feed directly on producers are called **primary consumers**. They are also called herbivores (herb, grass).

Animals that feed on primary consumers are called **secondary consumers**. Thus, elk, which feed on vegetation, are primary consumers, whereas wolves, because they feed on elk, are secondary consumers. There may also be third, fourth, or even higher levels of consumers and certain animals may occupy more than one position on the consumer scale. For instance, humans are primary consumers when they eat vegetables, secondary consumers when they eat beef and third-level consumers when they eat fish that feed on small fish that feed on algae. Secondary and higher order consumers are also called **carnivores** (*carni*, meat). Consumers that feed on both plants and animals are called **omnivores** (*omni*, all).

In a relationship in which one animal attacks, kills, and feeds on another, the animal that attacks and kills is called the **predator**; the animal that is killed is called the **prey**. Together, the two animals are said to have a **predator-prey** relationship.

Parasites are another important category of consumers. Parasites are organisms – either plants or animals – that become intimately associated with their 'prey' and feed on it over an extended period of time, typically without killing it (at least not immediately), but often weakening it so that it becomes more prone to being killed by other predators or by adverse conditions. The plant or animal that is fed upon is called the **host**; thus, we speak of a **host-parasite** relationship.

A tremendous variety of organisms may be parasitic. Various worms are well-known examples, but certain protozoans, insects, and even certain mammals (vampire bats) and plants (dodder) are also parasites. Many serious plant diseases and some animal diseases (such as athlete's food) are caused by parasitic fungi. Indeed, virtually every major group of organisms has at least some members that are parasitic. Parasites may live inside or outside their host.

In medical circles, a distinction is generally made between bacteria and viruses, which cause disease, and parasites, which are usually larger organisms. Ecologically, however, there is no real distinction. Bacteria are foreign organisms and viruses are organism-like entities feeding on and multiplying in their hosts over a period of time and doing the same damage as do other parasites. Therefore, disease-causing bacteria and viruses can be considered highly specialized parasites.

Detritus Feeders and Decomposers – Dead plant material such as fallen leaves, branches and trunks of dead trees, dead grass, the fecal wastes of animals, and occasional dead animal bodies is called **detritus** (pronounced di-Tri-tus). Many organisms are specialized to feed on detritus, and we refer to such consumers as **detritus feeders** or *detritivores*. Examples include earthworms, millipedes, crayfish, termites, ants, and wood beetles. As with regular consumers, one can identify ***primary detritus feeders*** (those that feed directly on detritus), s***econdary detritus feeders*** (those that feed on primary detritus feeders), and so on.

An extremely important group of primary detritus feeders is the **decomposers**, namely, fungi and bacteria. Much of the detritus in an ecosystem – particularly dead leaves and the wood of dead trees or branches – does not appear to be eaten as such, but rots away. Rotting is the result of the metabolic activity of fungi and bacteria. These organisms secrete digestive enzymes that cause the breakdown of wood, for example, into simple sugars that the fungi or bacteria then absorb for their nourishment. Thus, the rotting we observe is really the result of material being consumed by fungi and bacteria. Even though fungi and bacteria are called decomposers because of their unique behaviour, we group them with detritus feeders because their function in the ecosystem is the same. In turn, decomposers are fed upon by such secondary detritus feeders as protozoans, mites, insects, and worms. When a fungus or other decomposer dies, its body becomes part of the detritus and the source of energy and nutrients for still more detritus feeders and decomposers.

In summary, despite the apparent diversity of ecosystems, they all have a similar biotic structure. They can all be described in terms of autotrophs, or producers, which produce organic matter that becomes the source of energy and nutrients for heterotrophs, which are various categories of consumers and detritus feeders and decomposers.

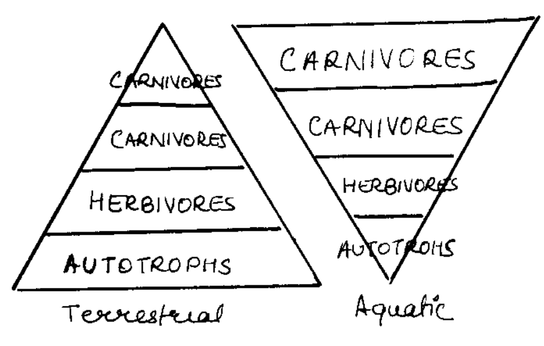
Feeding Relationships: Food Chains, Food Webs, and Trophic Levels – In describing the biotic structure of ecosystems, it is evident that major interactions among organisms involve feeding relationships. We can identify innumerable pathways where one organism is eaten by a second, which is eaten by a third, and so on. Each such pathway is called a **food chain**.

While it is interesting to trace such pathways, it is important to recognize that food chains seldom exist as isolated entities. An herbivore population feeds on several kinds of plants and is preyed upon by several secondary consumers or omnivores. Consequently, virtually all food chains are interconnected and form a complex web of feeding relationships. Indeed, the term **food web** is used to denote the complex network of interconnected food chains.

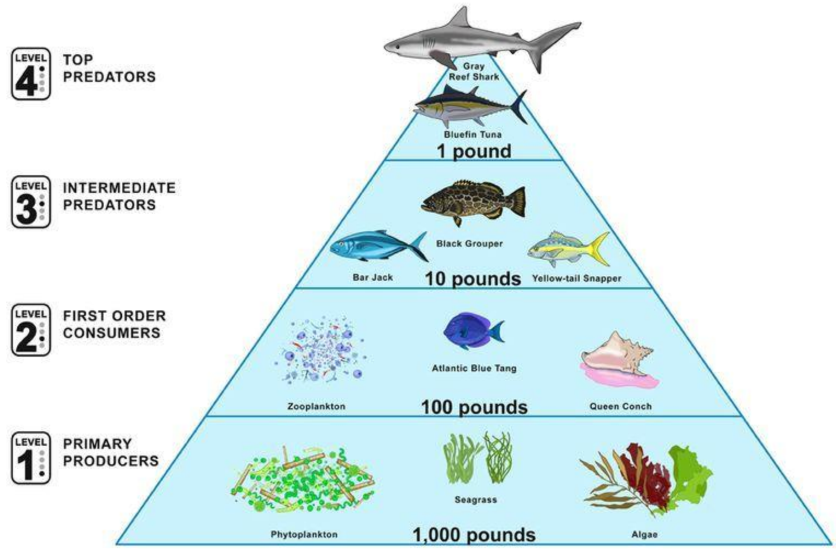
Despite the number of theoretical food chains and the complexity of food webs, there is a simple overall pattern: All food chains basically lead through a series of steps or levels – namely, from producers to primary consumers (or primary detritus feeders) to secondary consumers (or secondary detritus feeders), and so on. These feeding levels are called **trophic levels** (*trophic*, feeding). All producers belong to the first trophic level, all primary consumers (in other words, all herbivores), whether feeding on living or dead producers, belong to the second trophic level; organisms feeding on these herbivores belong to the third level, and so on.

Whether we visualize the biotic structure of an ecosystem in terms of food chains, food webs, or trophic levels, we should see, through each feeding step, that there is a fundamental movement of the chemical nutrients and stored energy they contain from one organism or level to the next.

Usually, no more than three or four trophic levels are there in an ecosystem. The **biomass**, or total combined (net dry) weight, of all the organisms at each trophic level can be estimated by collecting (or trapping) and weighing suitable samples. In terrestrial ecosystems, the biomass is about 90-99 percent less at each higher trophic level. If the biomass of producers in a grassland is 10 tonnes (20,000 lb) per acre, the biomass of herbivores will be no more than 2000 pounds and that of carnivores no more than 200 pounds. Clearly, you can't go through very many trophic levels before the biomass approaches zero. Depicting this graphically gives rise to what is commonly called a **biomass pyramid**.



The biomass decreases so much at each trophic level largely because much of the food that is consumed by a heterotroph is not converted to the body tissues of the heterotroph; rather, it is broken down so that the stored energy it contains can be released and used by the heterotroph. Hence, there is an inevitable loss of biomass with the movement to higher trophic levels. It is very significant to observe that all heterotrophs depend on the continual input of fresh organic matter produced by the autotrophs (green plants). Without such input, the heterotrophs would all run out of food and starve as the organic matter was broken down to release its stored energy.



As this breakdown or organic matter occurs, the chemical elements are released back to the environment in the inorganic state, where they may be reabsorbed by autotrophs (producers). Thus, there is a continuous cycle of nutrients from the environment through organisms and back to the environment. The spent energy, on the other hand, is lost as heat is given off from bodies.

In summary, all food chains, food webs, and trophic levels must start with producers, and producers must suitable environmental conditions to support their growth. Populations of all heterotrophs, including humans, are ultimately limited by what plants produce, in accordance with the concept of the biomass pyramid. Should any factor cause the productive capacity of green plants to be diminished, all other organisms at higher trophic levels will be diminished accordingly.

ECOLOGICAL SUCCESSION

Biotic communities are dynamic in nature and change over a period of time. The process by which communities of plant and animal species in an area are replaced or changed into another over a period of time is known as ecological succession. Both the biotic and abiotic components are involved in this change. This change is brought about both by the activities of the communities as well as by the physical environment in that particular area.

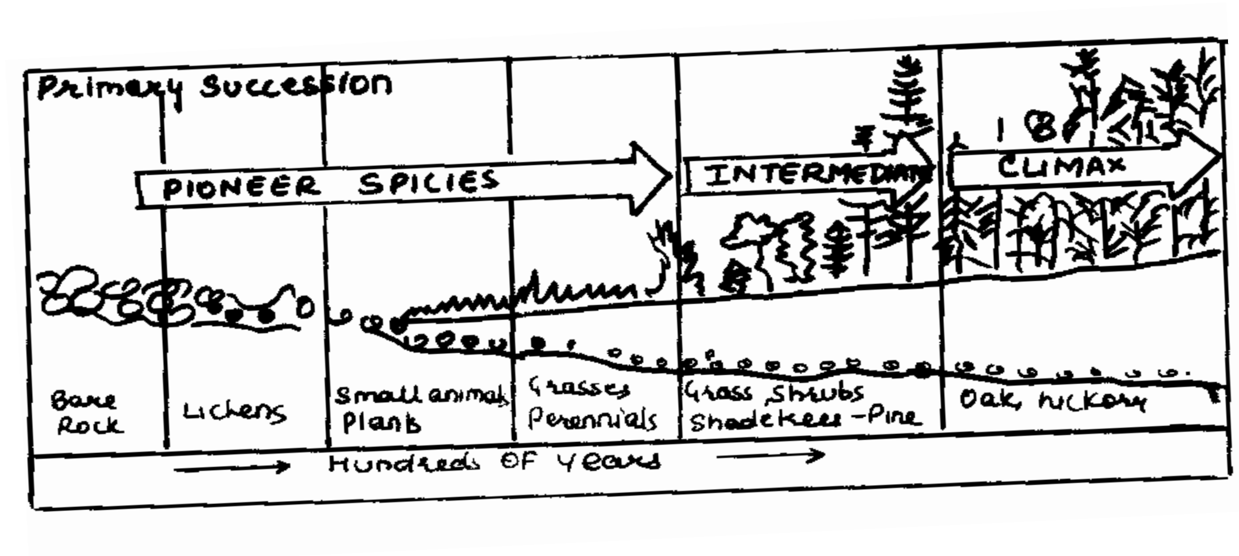
The physical environment often influences the nature, direction, rate and optimal limit of changes. During succession both the plant and animal communities undergo change. There are two types of successions (i) Primary succession and (ii) Secondary succession.

Primary succession

Primary succession takes place an over a bare or unoccupied areas such as rocks outcrop,newly formed deltas and sand dunes, emerging volcano islands and lava flows as well as glacial moraines (muddy area exposed by a retreating glacier). where no community has existed previously. The plants that invade first bare land, where soil is initially absent are called pioneer species. The assemblage of pioneer plants is collectively called pioneer community. A pioneer species generally show high growth rate but short life span.

Primary succession is much more difficult to observe than secondary succession because there are relatively very few places on earth that do not already have communities of organisms. Furthermore, primary succession takes a very long time as compared to secondary succession as the soil is to be formed during primary succession while secondary succession starts in an area where soil is already present.

The community that initially inhabits a bare area is called pioneer community. The pioneer community after some time gets replaced by another community with different species combination. This second community g

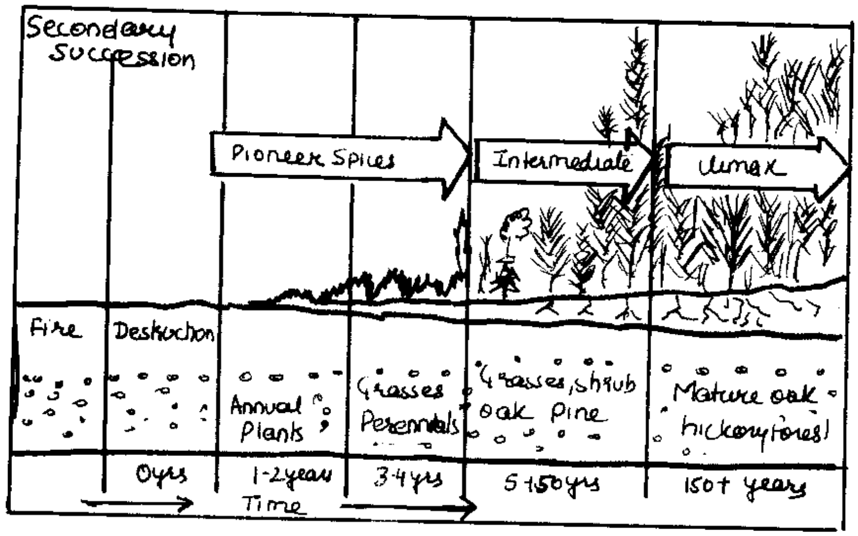


ets replaced by a third community. This process continues sequence-wise in which a community replaced previous by another community.

Each transitional (temporary) community that is formed and replaced during succession is called a stage in succession or a seral community. The terminal (final) stage of succession forms the community which is called as climax community. A climax community is stable, mature, more complex and long lasting. The entire sequence of communities in a given area, succeeding each other, during the course of succession is termed sere The animals of such a community also exhibit succession which to a great extent is determined by plant succession. However animals of such successional stages are also influenced by the types of animals that are able to migrate from

neighbouring communities. A climax community as long as it is undisturbed, remains relatively stable in dynamic equilibrium with the prevailing climate and habitat factors.
Succession that occurs on land where moisture content is low for e.g. on bare rock is known as xerarch. Succession that takes place in a water body, like ponds or lake is called hydrarch.

Secondary succession



Secondary succession is the development of a community which forms after the existing natural vegetation that constitutes a community is removed, disturbed or destroyed by a natural event like hurricane or forest fire or by human related events like tilling or harvesting land.A secondary succession is relatively fast as, the soil has the necessary nutrients as well as a large pool of seeds and other dormant stages of organisms.

Aquatic Succession

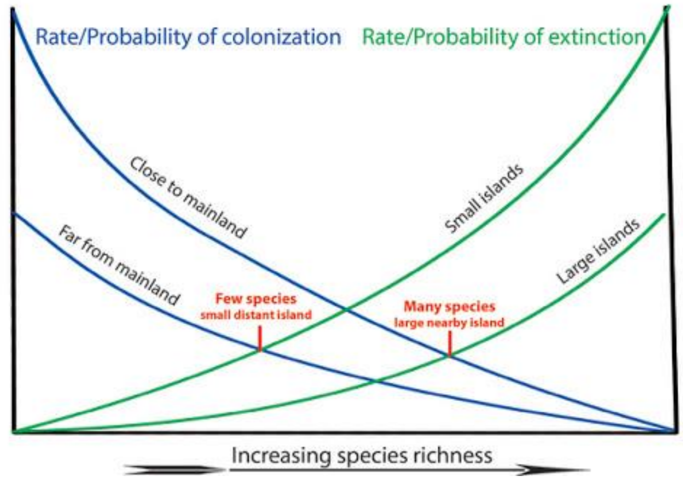
The process of succession also occurs in aquatic habitats as in a clear mountain lake just formed by a retreating glacier. The lake is much like barren rock; the water is low in nutrients and supports few organisms. As time passes, reeds and other water plants begin to grow in the thin sediments near the shore of the lake supporting other organism. Organic matter begins to collect in the lake.

As the lake begins to fill with sediment, the water becomes richer in nutrients. More organisms can survive, and water plants begin to cover the surface of the lake. Eventually the lake fills with sediment and becomes a marsh. Land plants begin to colonize the marsh. Finally, the lake becomes a fertile meadow covered with land plants and may ultimately turn into a forest.

Island Succession

Islands undergo succession in much the same way as land on the continents. New islands can form quickly through volcanic eruptions. Living things are quick to colonize this new land. Seagulls are observed nesting on some islands before the volcanic activity stops.

Islands are isolated by the water that surrounds them. Any organism found on an island must have ancestors that were carried there by water, wind, or by other organisms. These ancestors may have arrived on the island by chance alone. Many islands therefore have large bird populations, because birds can reach islands much more easily than land animals.



The rare organism that arrives on a new island and can find a mate is often faced with an opportunity. There are many unfilled niches on the island, because the organisms that would fill the niches on the mainland have no way of getting to the island. In this situation, the offspring of a few organisms can evolve to fill several niches. Populations of organisms adapt to their new niches, and several new species form. The offspring of a few ancestors can adapt to several different niches.

• The composition of all ecosystems keeps on changing with change in their environment. These changes finally lead to the climax community.

• Climax community - It is the community which is in equilibrium with its environment. Gradual and fairly predictable change in the species' composition of a given area is called ecological succession.

- Sere(s) - It is the sequence of communities that successively change in a given environment. The transitional communities are called seral stages or seral communities.
- Succession happens in areas where no life forms ever existed as in bare rocks, cool lava, etc. (primary succession), or in areas which have lost all life forms due to destructions and floods (secondary succession).
- Primary succession takes hundreds to thousands of years as developing soil on bare rocks is a slowprocess. Secondary succession is faster than primary succession since the nature does not have to start from scratch.
- During succession, any disturbances (natural/man-made) can convert a particular seral stage to an earlier one.
- Hydrarch succession - It takes place in wet areas and converts hydric conditions to mesic.
- Xerarch succession - It takes place in dry areas and converts xeric conditions to mesic.
- Pioneer species - These are the species that first invade a bare area. On land, these could be lichens that secrete enzymes to dissolve the rock surfaces for soil formation while in water, pioneer species could be phytoplanktons.