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COURSE HANDOUT

Intended for 3 rd year degree Ecology and environment (LMD).

Title:

Biology of populations and organisms

Developed by:

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The preface :

Understanding population from a biological perspective is important, as it can help explain how species evolve and how they interact with their environment. This course summary examines in detail the different aspects of population in biology, including Darwin's theory, ecology, ecosystem, species, population genetics and panmixis.

Charles Darwin is widely regarded as one of the pioneers of population biology. His theory of evolution by natural selection is one of the foundations of modern biology. Darwin argued that species evolve over time as a result of natural selection, a process by which individuals best adapted to their environment are more likely to survive and reproduce. The genetic traits that make them better able to survive are then passed on to their offspring, which can lead to changes in the population over time.

Two groups of different species living in the same area cannot be considered as a single population; because they are different species, they must be considered as two distinct populations. Similarly, two groups of the same species living in different areas are considered as two distinct populations.

Panmixis is an important concept in population genetics, referring to the random mixing of genes within a population of organisms. This occurs when individuals in a population reproduce randomly, and genes are passed on randomly to offspring.

Panmixis can help maintain genetic variability in a population, which can be important for its ability to adapt to changing environments. However, panmixy can also lead to the loss of certain genetic characteristics that are valuable for the population's survival, due to the dilution of favorable genes.

Finally, population in biology is a fascinating subject that addresses key elements of evolution, ecology and population genetics. The study of population in biology can help us better understand how populations of organisms evolve and how they are influenced by their environment and the relationships between species. It can also help us predict the consequences of environmental disturbances on populations of organisms and ecosystems, and develop strategies to preserve biodiversity and ecosystem health.

Population in biology - Key points :

-A species is a group of similar organisms that are able to reproduce and create fertile offspring.

-Most of the time, members of different species cannot produce viable or fertile offspring. This is because when parents don't have the same number of chromosomes, the offspring will have an odd number of chromosomes.

-A population is a group of individuals of the same species occupying a particular space at a given time, whose members can potentially interbreed and produce fertile offspring.

-Both abiotic and biotic factors affect population size.

-Interspecific competition takes place between species, while interspecific competition takes place within a species.

-Panmixis is an important concept in population genetics, referring to the random mixing of genes within a population of organisms. This occurs when individuals in a population reproduce at random, and genes are passed on to offspring at random.

The study of populations (dynamics, genetics, age or kinship structures...), in their spatial and temporal dimensions, is the best introduction to the fundamental mechanisms of ecology and evolution.

mechanisms of ecology and evolution. It is with this in mind that the present course should be approached.

At the end of this course, the learner will be able to knowledge of eco-biological populations (dynamics, genetics, age or kinship structures...), in their spatial and temporal dimensions, is the best introduction to the fundamental mechanisms of ecology and evolution. It is with this in mind that the present course should be approached.

To be able to follow this course successfully, you must have :

- basic knowledge of population genetics
- basic knowledge of ecology

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Biology of populations and organisms

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Introduction

The population occupies, in the hierarchy of life, an intermediate level between that of individuals and that of communities. We can define a population as a set of individuals of the same species who share a common habitat (and a community as a set of populations of different species, sharing a common habitat). Under these two apparently simple criteria (conspecificity, cohabitation) lies in fact a vast potential often complex interactions, linked in particular to the needs of reproduction, the inevitability of competition, or even the opportunities for cooperation.

If the criterion of conspecificity is relatively easy to evaluate (at least for sexual organisms), the same is not always true for that of cohabitation. Certain populations are naturally structured into easily identifiable local demes (for example lakes or ponds for a freshwater species), which will not prevent any interaction between demes, connected by a certain dispersal rate. Other populations appear continuous over a vast geographic scale, but without necessarily being panmictic. The sphere of interaction of a focal individual will in this case be limited to a restricted portion of the territory of the population, of variable size depending on the interactions considered (competition, reproduction, cooperation...). To the absolute criterion of cohabitation, we often prefer the relative one of neighborhood, more realistic but also more complex.

Conspecific, moreover, does not mean identical: each individual in a population is unique, and can differ from its neighbors on an incalculable number of characteristics (sex, age, size, color, experience, etc.), sometimes under the control of genes, sometimes from the environment, the more often of both.

This heterogeneity is one of the essential characteristics of populations, a fundamental component of ecological interactions. This is why this course will make extensive use of the concepts of diversity and variance (or covariance for bivariate distributions). So-called "aggregated" ecological models, which consider all individuals in a population as identical, are useful as a first approximation, but often incapable of accounting for certain crucial processes.

It then becomes necessary to use "structured" models, which categorize the individuals of the population into a (limited) number of discrete classes: age, size, location, etc. Taking these structures into account is particularly important for small populations, whose viability is crucially affected by demographic stochasticity. This intrinsic heterogeneity of populations is equally important with regard to evolutionary processes. With Darwin and the advent of the theory of evolution, the typological conception of the species was replaced by a population conception.

Simultaneously, the concept of variance has changed status: simple background noise in the typological conception, variance becomes an essential, fundamental element in the new paradigm: there can be no selection, and therefore no evolution, without differences.

The analysis of variance, its decomposition into different parts (environmental, additive genetics, etc.) is therefore crucial for understanding the mechanisms of evolution. All evolutionary processes are, moreover, populational in nature: it is the individuals who are subject to selection (the evolutionary balance maximizes individual fitness, not necessarily that of the population), but it is the populations which evolve, it is that is, multivariate distributions of characters, with their means, variances, and covariances. The study of evolution must therefore also be conceived as an analysis of the dynamics of variance: eroded by drift, restored by mutation, redistributed by migration or sexuality, and exploited by selection. Closely associated with this genetic variance is the concept of kinship; the individuals of a population are more or less genetically close to each other, that is to say more or less related; we know, since WD Hamilton and his discovery of kin selection, the fundamental role that kinship structures play in the evolution of all characters linked to social interactions: sex ratio, dispersion, altruism, to name a few. only a few.

The study of populations (dynamics, genetics, age or kinship structures, etc.), in their spatial and temporal dimensions, thus constitutes the best introduction to fundamental mechanisms of ecology and evolution. It is with this in mind that we must approach this course.

Chapter I: Concepts in ecology

I. Concepts in ecology

I.1. History of ecology

Ecology is a very polymorphous discipline, mainly formed from the 19th century around several currents of thought. Deléage (1991) *in* [1] identified three main ones, the botanical current, the geological current and the population current. Contrary to the assertions of some authors, there is nothing "ecological" in the writings of Aristotle, Linnaeus or even Buffon. It was not until the plant geography of the 19th century that the conceptual framework was formed for the development of central concepts of ecology.

We know that the word oekology was created in 1866 by one of Charles Darwin's most ardent disciples, Ernest Haeckel, to which he gave the following meaning [1] :

- "Science of the economy, the way of life, the external vital relationships of organisms";

- "By oekology we mean the totality of the science of the organism's relations with the environment, including, in the broad sense, all conditions of existence";

- And, in 1868 "oecology or geographical distribution of organisms...".

I.2. Definition of the term ecology

"By ecology we mean the science of all the relationships of organisms among themselves and with the outside world." [1-3].

We consider ecology as the science of the relationships of living beings with their environment; living beings being closely integrated into their "environment", ecology is the science of complex functional biological systems called "ecosystems": it also includes the study of the relationships between living beings.

"Defined as the study of the relationships of organisms with their environment, or as the study of the interactions which determine the distribution and abundance of organisms, or as the study of ecosystems, ecology opens a wide field, from physiology to biogeography. From this angle, it is a kind of general biology of organisms, a naturalist approach to the living world." [1, 2-6]

"Ecological theory spans a large range of topics, from the physiology and behavior of individuals or groups of organisms, through population dynamics and community ecology, to the ecology of ecosystems and the biochemical cycles of the entire biosphere. Ecology theory also embraces large parts of evolutionary biology, including paleontology and systematics, and the earth sciences, especially oceanography and tectonics. "Ecology is the study of the interactions between living organisms and the environment, and of living organisms with each other under natural conditions."

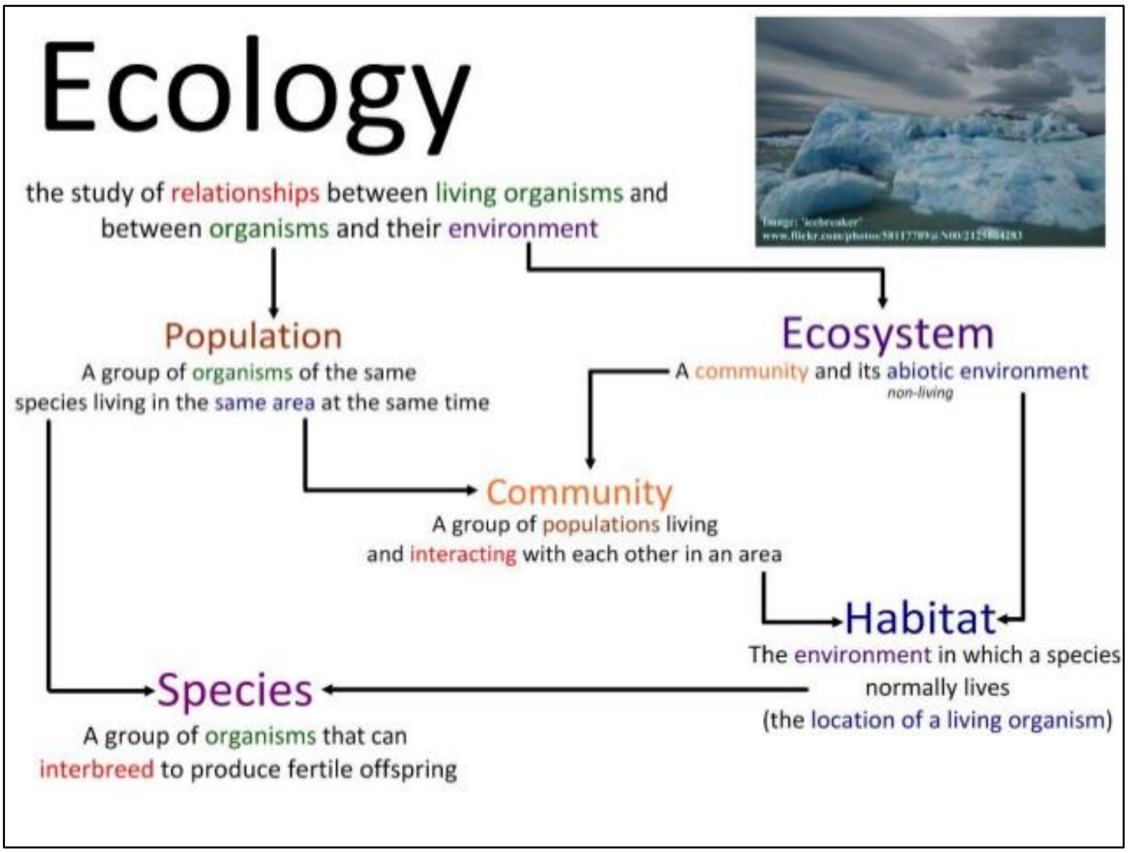


Figure 1. Definition of the term ecology.
(https://www.google.com/url?sa=i&url=https%3A%2F%2Fibiologia.com%2Fecologies-definition%2F&psig=AOvVawlMJ6FnxqlhUMaLnRIMluiv&ust=1728923949585000&source=images&cd=vfe&opi=89978449&ved=0CBQQjRxqFwoTCLioyOTIi4kDFQAAAAAdAAAAABAE).

I.3. Axis of intervention

An individual : organism refers to a single living entity, such as a human, animal, or plant, that possesses a unique genome and exhibits various traits and behaviors influenced by genetic and environmental factors.

A population : is defined as a group of individuals of the same species living and interbreeding within a given area. Members of a population often rely on the same resources, are subject to similar environmental constraints, and depend on the availability of other members to persist over time.

A community : community, in biology, an interacting group of various species in a common location. For example, a forest of trees and undergrowth plants, inhabited by animals and rooted in soil containing bacteria and fungi, constitutes a biological community. A brief treatment of biological communities follows.

Ecosystem : The best definition of an ecosystem is : the living organisms and their environment interacting in a certain area.

Ecosphere : is the area on and around the earth where life exists. Organisms can only survive outside the ecosphere in an artificially protected environment, like a spaceship.

Biosphere : is defined as the region on, above, and below the Earth's surface where life exists. The biosphere is a narrow zone on the surface of the earth where soil, water, and air combine to sustain life.

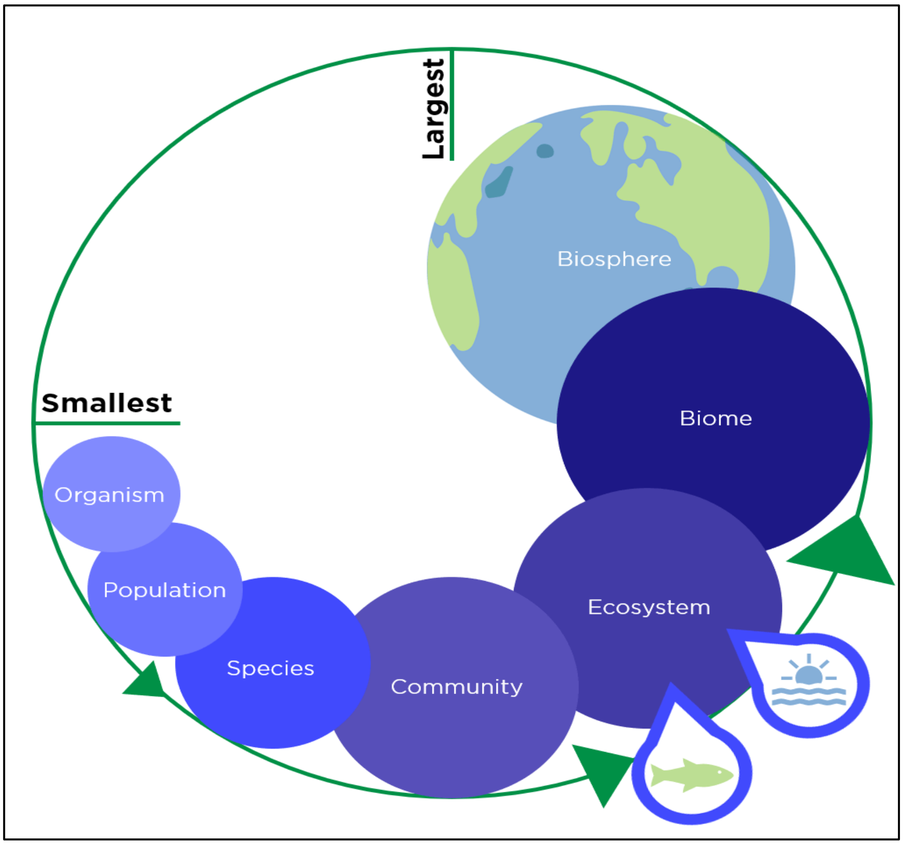


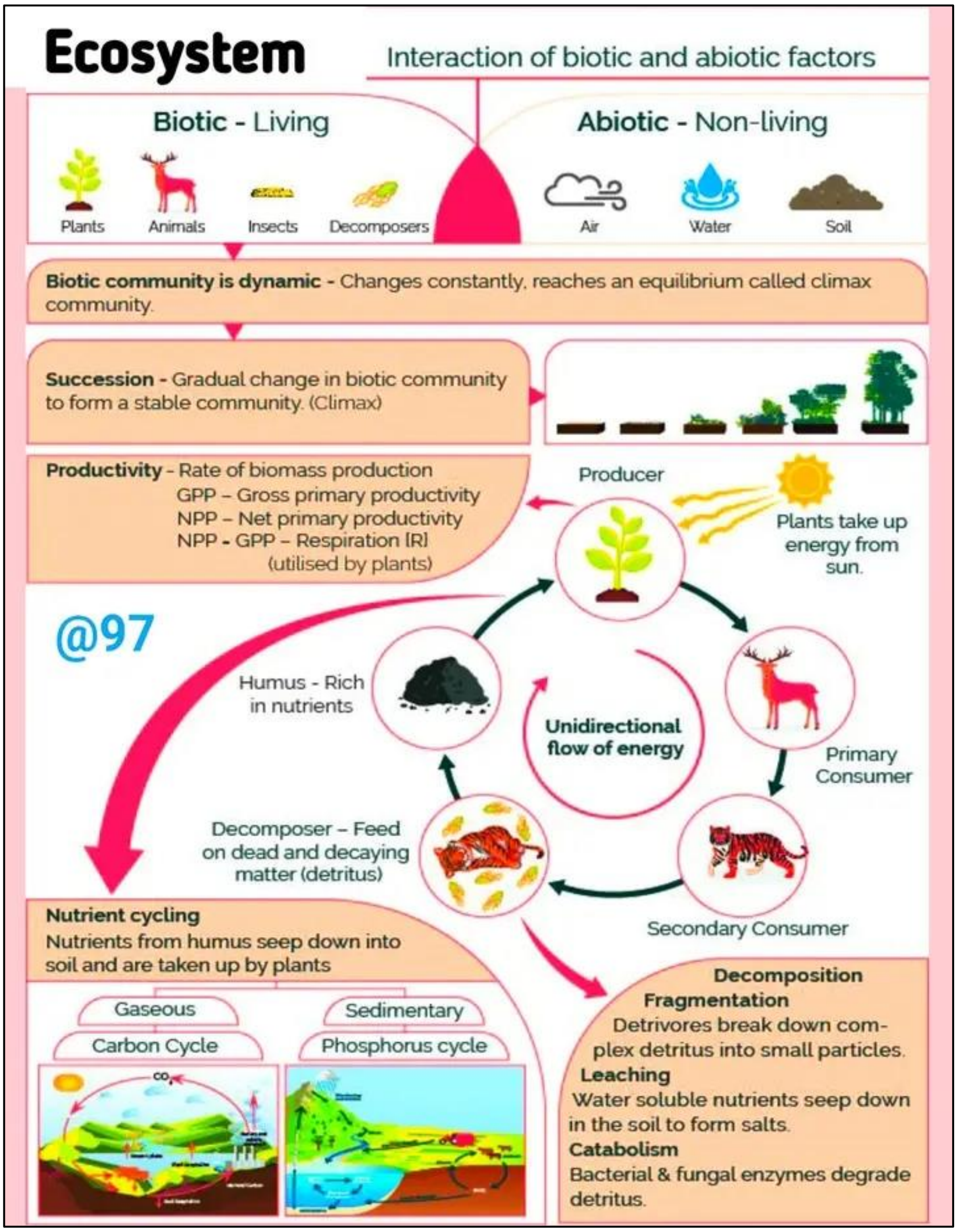
Figure 2. Axis of intervention of ecology. (https://www.expii.com/t/ecosystem-ecology-definition-examples-10285).

I.4. Concept of the ecological system

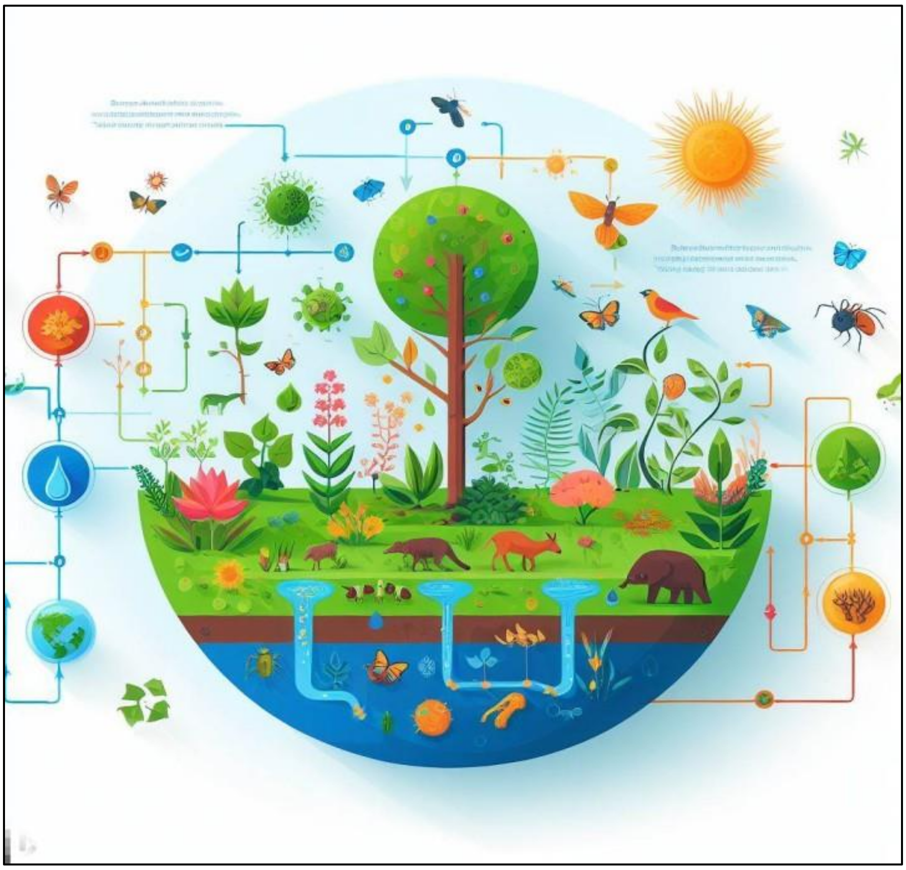
The object immediately given or accessible to the naturalist is an individual. Individuals, which we first perceive as isolated in nature, only have meaning, for ecology, through the system of relationships which link them, on the one hand to other individuals, and on the other hand to their physico-chemical environment [6,7,8]

The fundamental unit, the elementary part of these ecological systems is the population, set of individuals of the same species coexisting in the environment considered.

The concrete delimitation of ecological systems depends on the objective of the study and the state of knowledge in the field. We can, for example, be interested in the dynamics of a particular population and then define the system to be studied by the network of relationships, direct or indirect, that it presents with the other components, biotic and abiotic, of its environment.



(a)



(b)

Figure 3 (a and b). Concept of the ecological system.
(https://www.linkedin.com/pulse/what-keeps-our-ecosystem-balanced-edwin-cornelius-p6xmf).

I.5. Dynamics of ecological systems and evolution

Ecological systems are not immutable structures. They can change over time, transform or disappear. The populations that constitute the biological framework of ecosystems are not in fact fixed entities, variable only in their numbers or their demographic structures. Reflections of a long history, of which their genetic pool keeps track, natural populations remain exposed to multiple selective pressures and are therefore subject to evolution. The ecologist may thus have to know population genetics, just as specialists in this discipline must be concerned with the dynamics of the ecological systems in which the populations they study develop.

The genetic variability of natural populations thus appears to be a fundamental property of ecological systems. This must be taken into account both in terms of theoretical considerations and in terms of applications, whether it concerns conservation, management or exploitation of populations or ecosystems [9, 10].

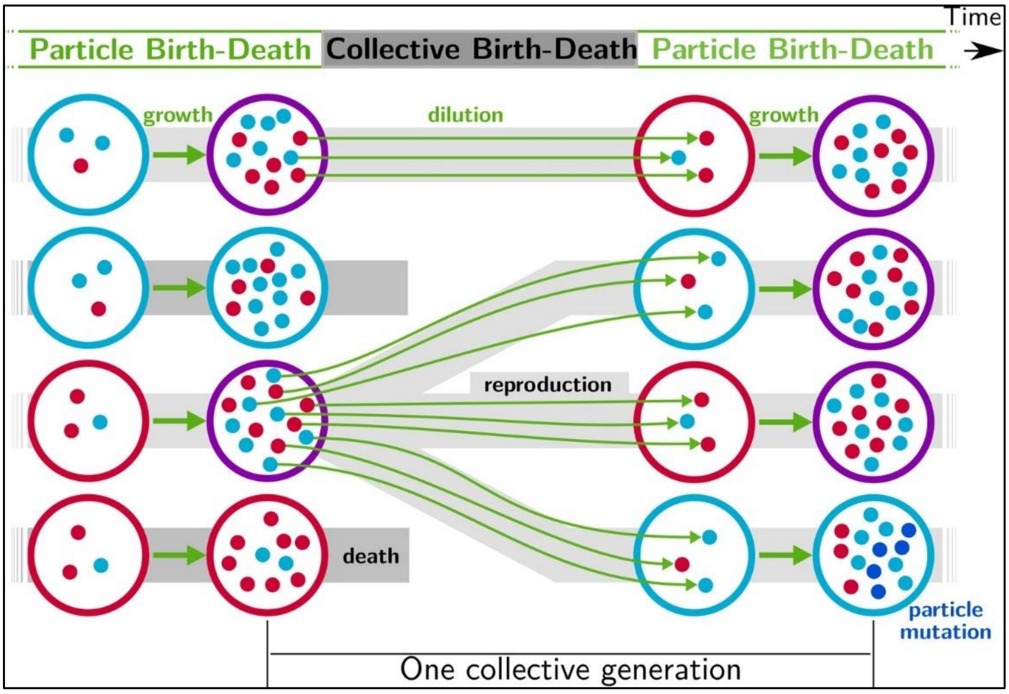


Figure 4. Dynamics of ecological systems and evolution.
(https://elifesciences.org/articles/53433).

I.6. Ecosystem dynamics and biosphere balance

Among all the species that have appeared on the surface of the globe, one today occupies a very particular position, central one could say: the human species. In fact, following its demographic and economic success and because of its skills, it finds itself faced with an unprecedented responsibility in history: managing planet Earth, and particularly the biosphere whose balance appears to be threatened. This is the great challenge of the 19th century for man. Certainly, with agriculture, forestry, hunting, fishing or breeding, man has been doing this for a long time. But until now it has done so on a local, regional scale, whereas today it is a matter of moving to a global scale. In fact, the looming changes, climatic and others (pollution, deforestation, rural abandonment), linked to the demographic and economic explosion of our population, affecting the biosphere as a whole. If we want to understand this complex dynamic, it is necessary to take into account two main types of processes which constitute its framework [10] :

a) Biodemographic processes, which are expressed through fluctuations in the number of individuals within animal or plant populations, through species flows (extinction, colonization, speciation);

b) Biogeochemical processes, which result in cycles of chemical elements (release or fixation of gases, decomposition of organic matter) and energy flows.

Thus, the dynamics of ecosystems, an elementary part of the biosphere, appears closely linked to the dynamics of species. This approach renews what has today become a real science, conservation biology, and results in the need to analyze biological diversity through its two components, specific richness and genetic variability in relation to the dynamics of multi-species systems which organize it (competition, predation, parasitism, "disasters"...).

I.7. The environment and its elements

Ecological niche : is a term for the position of a species within an ecosystem, describing both the range of conditions necessary for persistence of the species, and its ecological role in the ecosystem. (example : The Kirtland's Warbler and Dung beetle are examples of animals that occupy a distinct ecological niche) [11-15].

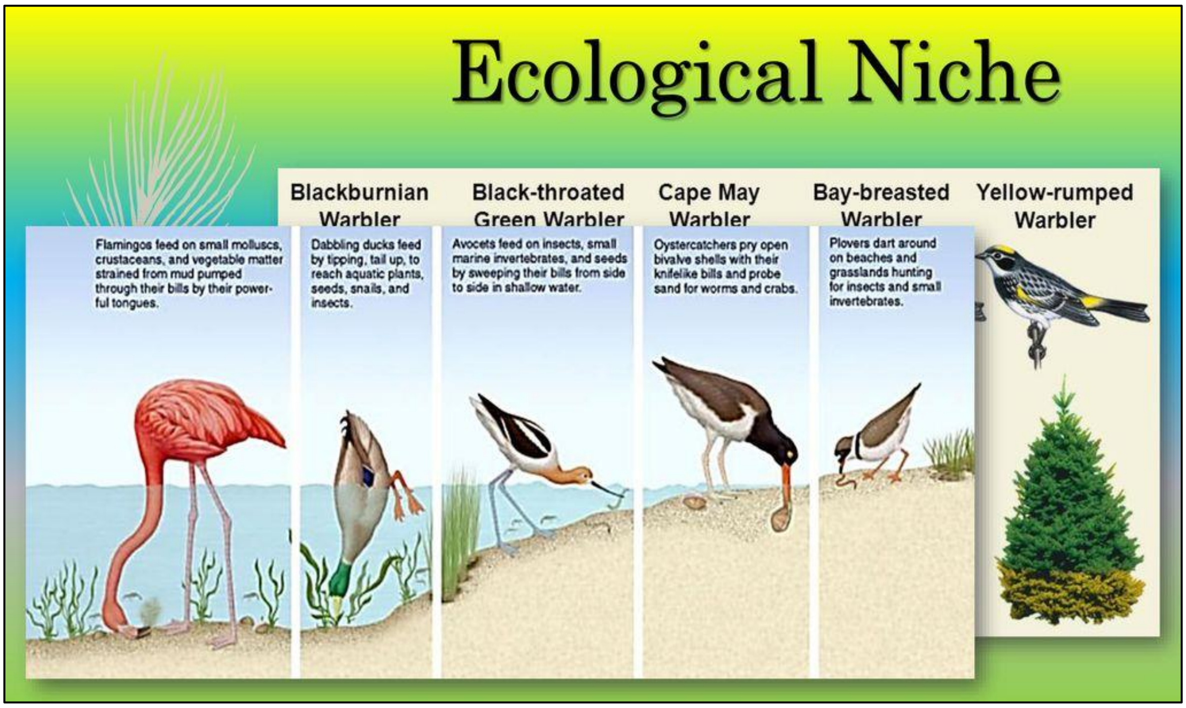


Figure 5. Ecological niche.
(https://www.google.com/url?sa=i&url=https%3A%2F%2Fslideplayer.com%2Fslide%2F17300069%2F&psig=AOvVaw2aPeScEVpSHRYOh4P9jD3&ust=1728924372076000&source=images&cd=vfe&opi=89978449&ved=0CBQQjRxqFwoTCOi5063ni4kDFQAAAAAdAAAAABAE).

A habitat : is the natural home or environment of a plant, animal, or other organism. It provides the organisms that live there with food, water, shelter and space to survive. Habitats consist of both biotic and abiotic factors. Biotic factors are living things. (In ecology, habitat refers to the array of resources, physical and biotic factors that are present in an area, such as to support the survival and reproduction) [13,14,15].

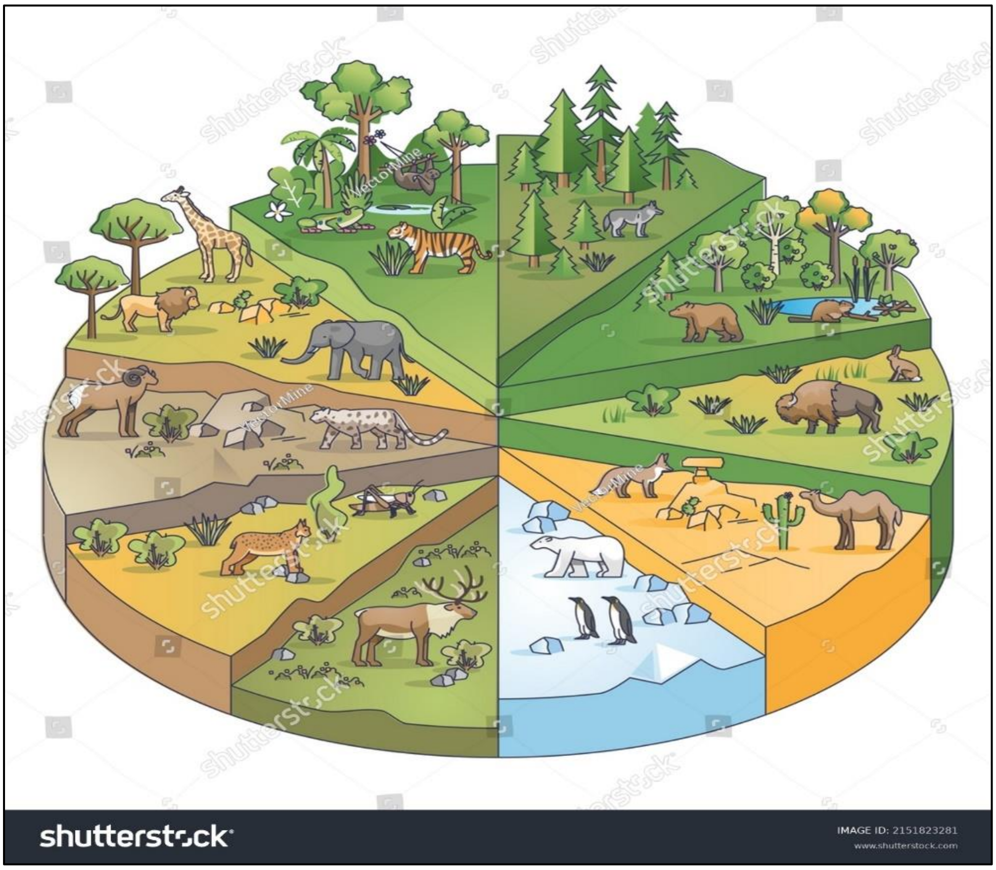


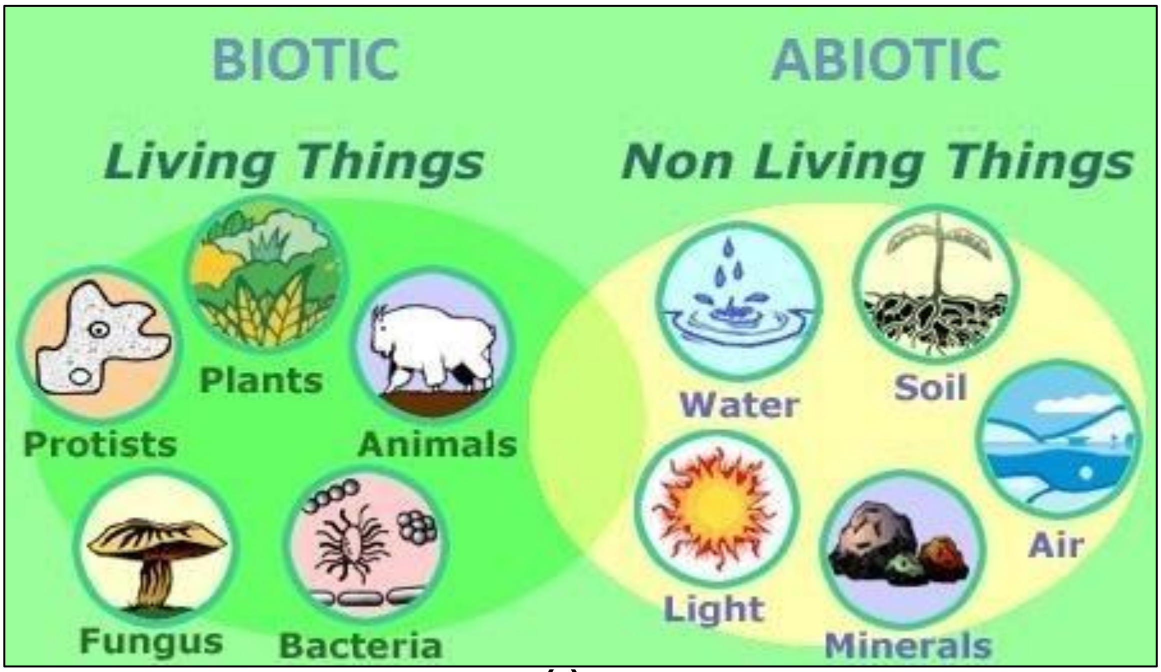
Figure 6. Different habitat.
(https://www.shutterstock.com/fr/image-vector/types-habitats-various-ecosystems-collection-pie-2151823281).

I.8. Concept of environmental factors

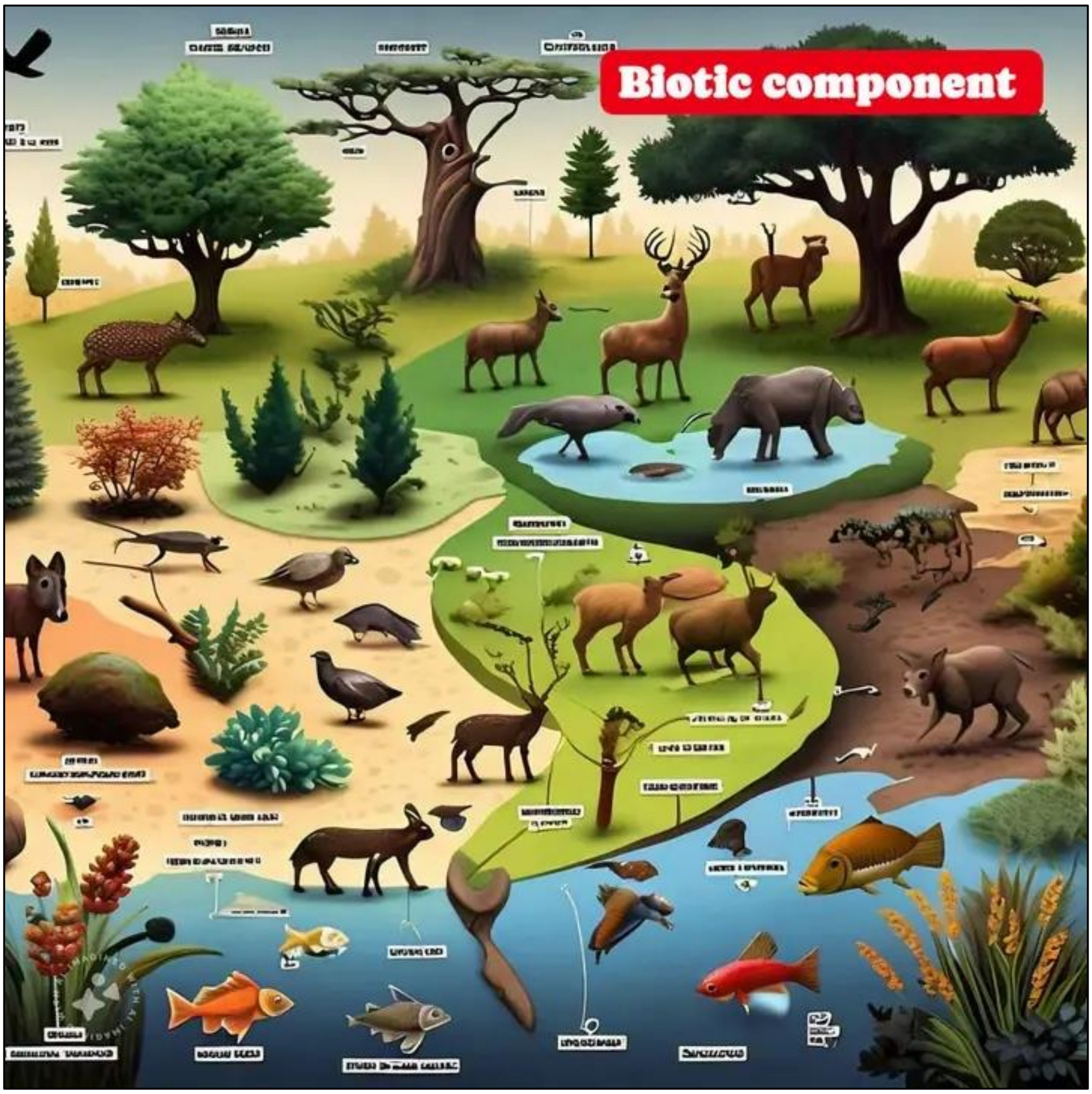
An ecological factor is any element of the environment that can act directly on living beings. Ecological factors are of two types [15] :

-Biotic factors: a set of interactions that exist between individuals of the same or different species; predation, parasitism, competition, symbiosis, commensalism, etc.

- Abiotic factors: Set of physicochemical characteristics of the environment such as climatic factors (temperature, rainfall, light, wind, etc.), edaphic factors (texture and structure of the soil, chemical composition, etc.).


BIOTIC
ABIOTIC
Living Things
Non Living Things
Plants
Protists
Animals
Fungus
Bacteria
Water
Soil
Air
Light
Minerals

(a)


Biotic component

(b)

(c)

Figure 7 (a, b and c). Abiotic and biotic factors Diagram.
(https://quizlet.com/293391367/abiotic-and-biotic-factors-diagram/).

I.9. Interaction of the environment and living beings

A- Law of tolerance : The law of tolerance or environmental maximum, first developed by Shelford (1913) *in* [1] , states that 'the success of a species, its number, sometimes its size, etc., are determined largely by the degree of deviation of a single factor (or factors) from the range of optimum of the species'**.**

B- The ecological valence : of a species represents its capacity to support greater or lesser variations of an ecological factor. She represents the ability to colonize or populate a given biotope [12-15].

- ✓ A species with high ecological valence, that is to say capable of populate very different environments and tolerate variations important to the intensity of ecological factors, is called Euryetius.
- ✓ A species with low ecological valence will only be able to support limited variations in ecological factors, it is called Stenoece.
- ✓ A species with an average ecological valency is called Mesoeceous.

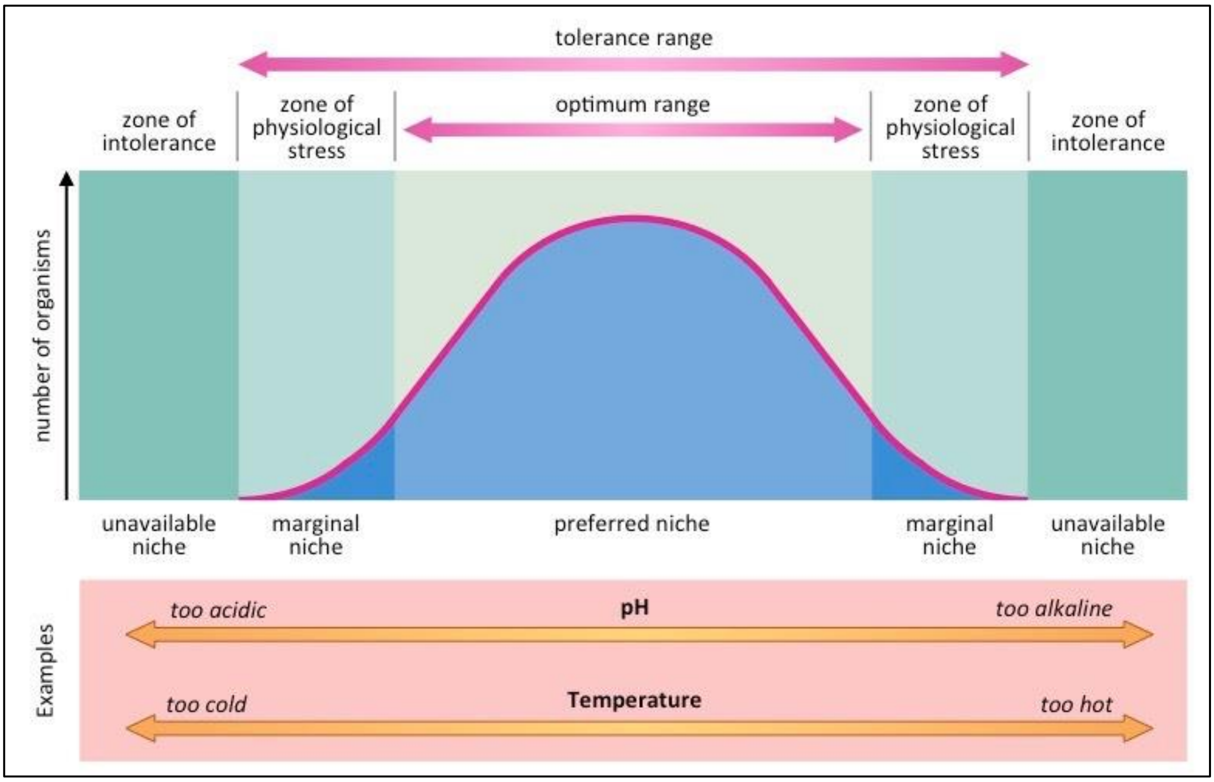


Figure 8. Law of tolerance diagram.
(https://old-ib.bioninja.com.au/options/option-c-ecology-and-conser/c1-species-and-communities/survival-factors.html).

C- Law of the minimum : Liebig's law of the minimum states that in environments where multiple nutrients are in low concentrations, the most limiting of these will determine the population density of the organism [15].

D- Limiting factor : is anything that constrains a population's size and slows or stops it from growing. Some examples of limiting factors are biotic, like food, mates, and competition with other organisms for resources [15].

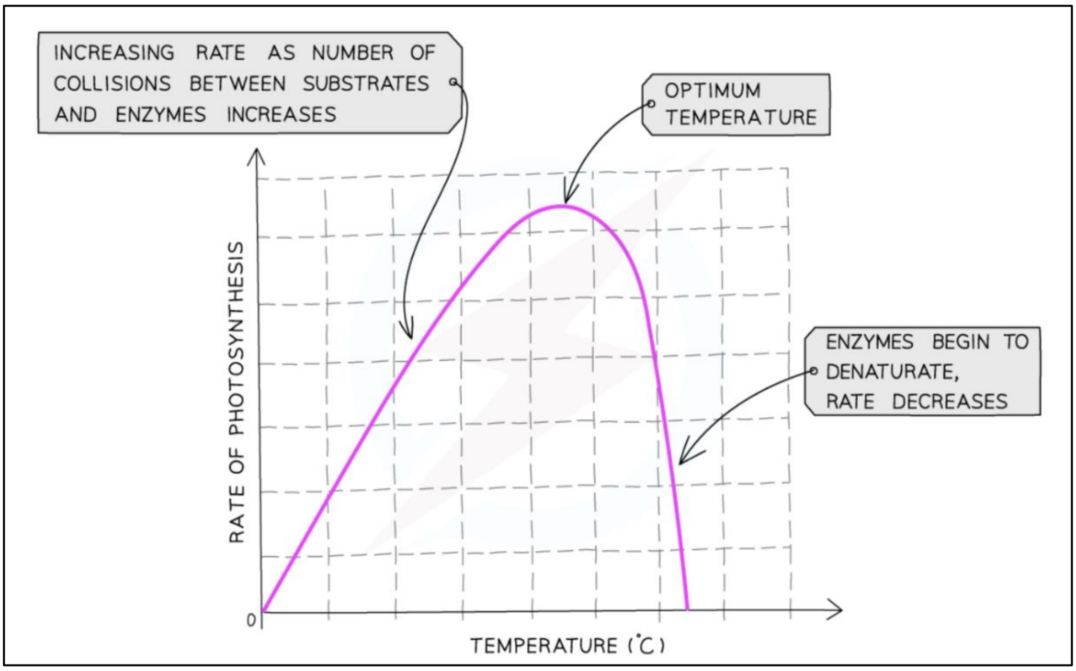


Figure 9. Limiting factor.
(https://www.out-class.org/blogs/limiting-factors-photosynthesis-graphs).

Chapter II: Population dynamics

II. Population dynamics

II.1. Population and biocenos

The population constitutes the fundamental unit of any biocenosis. The animal and plant communities specific to each ecosystem are in fact always the expression of the gathering of a large number of different populations belonging to one or other of the great kingdoms of living beings, which interact with each other. .

A population constitutes an ecological entity which has its own characteristics. The latter are optimally expressed by a set of statistical functions, which strictly concern the group of organisms concerned and not the individuals who compose it. Thus, birth rate, mortality, age class distribution, sex ratio, dispersion, etc., represent all specific entities of a set of individuals and not isolated individuals.

II.2. Main ecological parameters specific to populations

II.2.1. Density and relative abundance : Knowledge of the density of a population constitutes a primordial demoecological parameter. Density is expressed in number of individuals relative to unit area, the latter being chosen taking into account the greater or lesser abundance and (or) size of the species studied. Thus, we will generally express the density of ungulates in an African savannah in number of individuals per km^2. That of trees in a temperate forest in number of subjects per hectare. That of litter arthropods in number of individuals per m^2. Other units, such as the biomass of the population studied, can be adopted to express this density. Thus, we will talk about a density of 500 kg of fish per hectare of pond or 3.8 t of antelopes per km^2 of savannah. For each living species there is a maximum and minimum density of its populations that can be observed in nature and which can be maintained permanently. Thus, in a temperate forest, we will never be able to find densities as high as 10,000 deer per km^2 or, conversely, as low as 20 spiders per ha [1, 15].

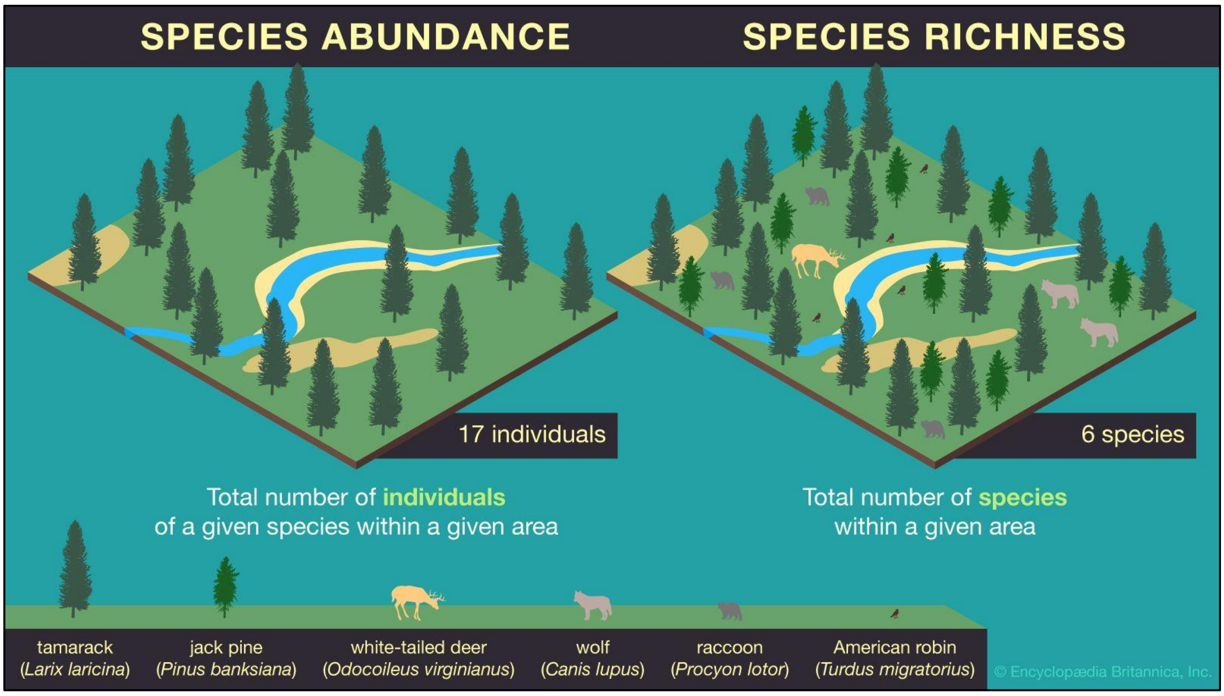


Figure 10. Relative abundance.
(https://www.britannica.com/science/relative-abundance).

II.2.2. Birth and mortality

The density of a population, its growth, or its decline, depend on the number of individuals added to it (birth rate) and those who disappear (mortality, emigration). In other words, the numbers of each species mainly depend on the difference between birth and death rates and the balance between emigration and immigration.

The birth rate is the main factor in population growth. We always distinguish between the maximum (or even physiological) birth rate and the real birth rate. The first reflects the biotic potential of the species considered [15].

The crude birth rate is expressed as a proportion of the total population: 50 births per 1000 individuals per year for example. In contrast, the net reproduction rate refers to the total number of females produced by each fertile female. This is the multiplication rate per generation. Mortality constitutes the second demoecological parameter of fundamental importance. In the same way as the birth rate, mortality varies depending on the age group considered. It is expressed by the mortality rate or by the probability of death. The mortality rate characterizes the number of deaths occurring in a given time interval, divided by the number at the start of the interval. Ecological, or real, mortality, characterizing the disappearance of individuals in given environmental conditions, is not yet constant, but varies depending on the population considered and environmental factors.

The study of demoecological phenomena requires dividing the population into a certain number of groups or age classes and monitoring their development over time. Depending on the possibilities, we will study generations of cohorts. The generation corresponds to all individuals born at the same time or; if the species has a significant longevity, to all individuals born in the same year. The cohort is made up of a group of individuals who are not necessarily the same age but who experienced the same original event. Thus, in a forest, all the trees having the same trunk diameter at 1.3 m in height constitute a cohort [15].

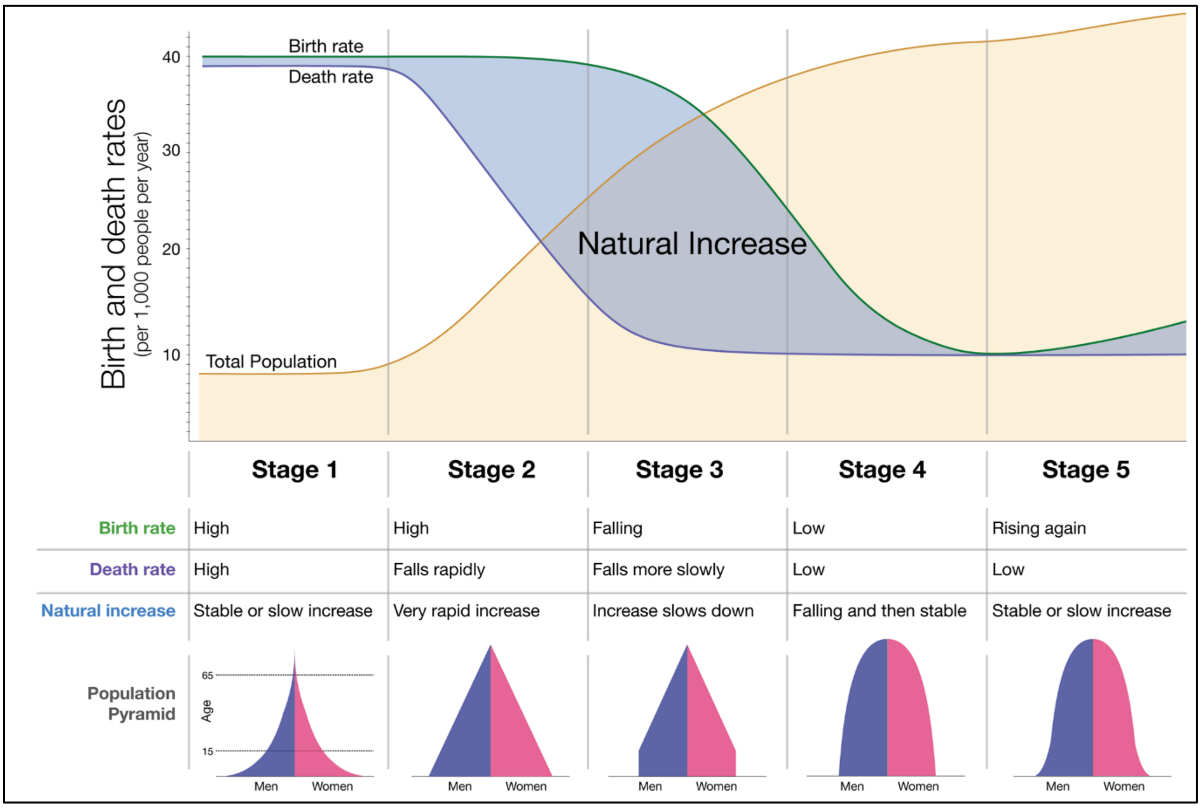


Figure 11. Birth and mortality of population.
(https://www.google.com/imgres?q=Birth%20and%20mortality%20of%20population&imgurl=https%3A%2F%2Flookaside.fbsbx.com%2Flookaside%2Fcrawler%2Fmedia%2F%3Fmedia_id%3D587998074736690&imgrefurl=https%3A%2F%2Fwww.facebook.com%2FOurWorldinData%2Fphotos%2Fa.256547964548371%2F587998074736690%2F%3Ftype%3D3&docid=Kt6QJD__MA-OCM&tbnid=Z4uDbqZtyd-KVM&vet=12ahUKEwiqv-zb94uJAxV-5Q6QEHVGGMU8QM3oECBkQAA..i&w=2048&h=1546&hcb=2&ved=2ahUKEwiqv-zb94uJAxV5Q6QEHVGGMU8QM3oECBkQAA).

II.2.3. Sex ratio

The sex ratio refers to the compared rate of males and females within a population of a species. It constitutes a demo-ecological parameter of great importance: this ratio can affect the success of reproduction. It also allows us to give an idea of the evolution of the population by analyzing the number of females available and capable of reproducing. Typically, animal species are gonochoric, that is, with separate sexes, although hermaphroditism or parthenogenesis may be common in some orders of invertebrates [15].

II.2.4. Age pyramids

They make it possible to obtain an interesting representation of the age class structure of a population. These are built by superimposing rectangles of constant width and length, and therefore surface area, proportional to the numbers in each age group. Males and females are arranged in two distinct groups located on either side of a median since mortality does not affect both sexes equally depending on age [10-15].

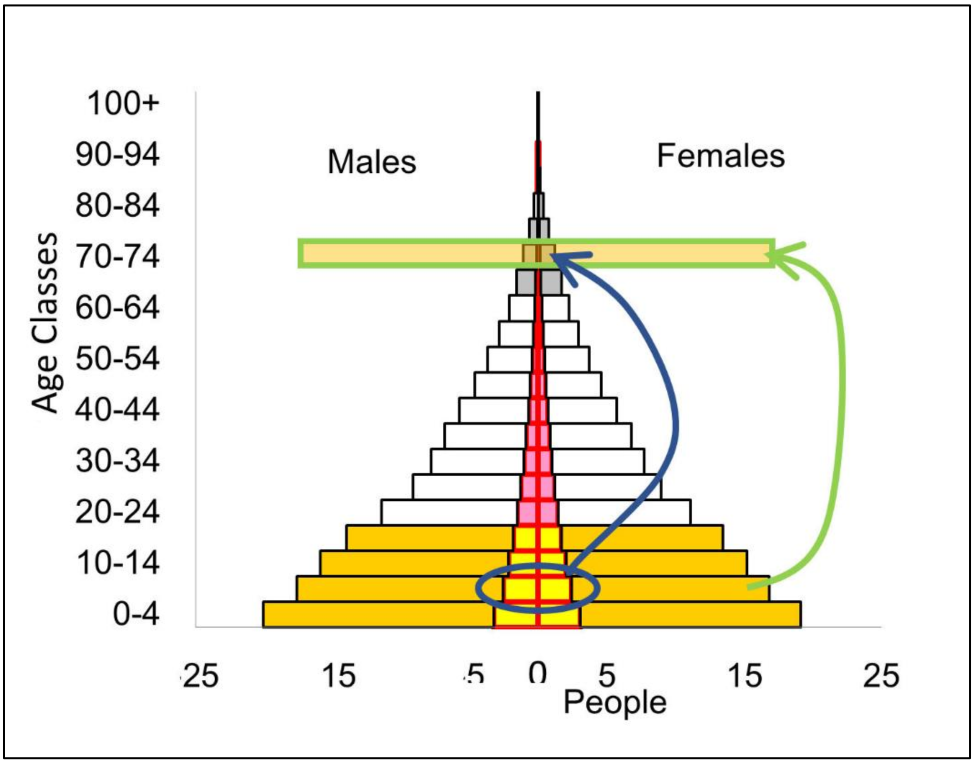


Figure 12. Types and Significance of Population Pyramids.

II.3. Population growth laws

II.3.1. Intrinsic rate of natural increase and exponential growth

When an environment temporarily offers natural resources in superabundant quantities, the populations that populate it will be able to grow without limiting factors hindering this growth. We can experimentally, in the laboratory, place yeasts or insects in such conditions. Let us also not forget that the human species, thanks to advances in medicine, agricultural production, etc. has artificially eliminated any limiting factor and is experiencing such favorable conditions that it has resulted in an unprecedented demographic explosion in the history of the biosphere. In the absence of limiting factors, we see that the rate of increase in numbers per unit of time remains constant. Let N0 be the number at time T0, N that at time t, this rate of increase per individual R will have the expression [15] :

$$R = \frac{(N - N_0)}{N(t - t_0)} = \frac{\triangle N}{N \triangle t} \qquad (1)$$

When $\triangle t \longrightarrow 0$, $R \longrightarrow r$ and (1) becomes:

$$r = \frac{dN}{N\,dt} \qquad (2)$$

"r" is called the intrinsic rate of natural growth, it is a constant characteristic of the species considered. It expresses the biotic potential of this species, that is to say the maximum fertility which it can demonstrate in the absence of limiting factors.

As a general rule, we know the rate of increase R (per unit of time: days, months, years or per generation), the increase per individual in numbers following reproduction will be after one year (if R is expressed in proportion annual population increase):

We deduce: $r = \log(1+R)$

Thus, for the human species whose annual growth rate R is of the order of 1.2% at present, the calculation gives r = 0.0119; value little different from 0.012.

On the other hand, we can no longer make this approximation for high growth rates. Thus, in the case of a species having a growth rate of its numbers of 150% per year, i.e. R = 105 we find r = 0.916.

II.3.2. Law of population growth in the presence of limiting factors

In natural populations, the cumulative effect of the various limiting factors specific to the environments to which they are subject will prevent the biotic potential from being expressed by reducing the birth rate b, and increasing the mortality m, the overall influence of these factors limiting ecological constraints reflect the resistance of the environment, which will be even more opposed to the increase in numbers as the population in question becomes more numerous. These factors, both intrinsic (that is to say specific to the species considered) and extrinsic (linked to the environment) combine their effects to adjust the numbers to a given value, at which they will plateau.

The mathematician Verhulst (1938) *in* [1] , who was the first to propose a theory of population growth in an environment with limited capacities, considered that, under such conditions, the growth rate R decreases linearly as a function of the population. N:

$$R = r * \left(1 - \frac{N}{k} \right)$$

Where r is the intrinsic rate of natural growth in the absence of limiting factors (expression of the biotic potential of the species) and K is the limiting capacity of the environment, i.e. the maximum number that the population is capable of to wait.

II.3.4. Fluctuation of natural populations over time

In natural populations, fluctuations in numbers and not their constancy constitute an absolute rule, even if in many cases, the latter demonstrate relative stability when studied over a fairly long period. As early as 1756, the famous naturalist Buffon wrote in one of his works that all plant and animal populations, including the human species, presented fluctuations due to the existence of environmental factors which had a negative effect: diseases, overcrowding and lack of food, predation. He came to the conclusion that populations fluctuate between a lower and upper limit as a result of variations in death and birth rates. Depending on climatic conditions, diet and interspecific competition will be more or less favorable; the growth rate of the workforce R will be positive if ($b > m$), zero ($b = m$), or negative ($b < m$), leading, depending on the case, to growth, a plateauing or a reduction in the workforce [12-15].

II.3.5. Stable populations

This term refers to natural populations which exhibit low amplitude oscillations around an average value. They generally characterize large species living in environments where biotic factors are restrictive (intense competition for example) and therefore exert a determining action. As an example, we cite the case of populations of dominant trees in a primitive forest whose density per hectare varies little even over periods of more than a decade [10].

II.3.6. Cyclical populations

The majority of animal species, but also many herbaceous plant species (annual plants), or growing in a restrictive environment (plants from the Sahelian zones for example), present cyclical variations, of significant amplitude and sometimes even very considerable, of their workforce [11, 15].

II.3.7. Spatial distribution of populations

It is extremely rare for the individuals constituting a natural population to be distributed regularly over the surface of their biotope, except in the case of cultivated plants. A remarkable example of regular distribution is the distribution of bee larvae on the combs of the hive, which are made up of hexagonal cells whose arrangement is perfectly regular. As a general rule, plant species are made up of randomly distributed individuals, while animal populations very often have a distribution in aggregates. However, this last type of distribution is also quite common among large plants - arborescent or arboreal - because the distribution of plants and middle-aged plants is conditioned by that of older trees known as seed-bearing trees. Individuals that descend from the same seed carrier tend to congregate in the vicinity of the latter. In higher animals, this aggregation of individuals can result from social attraction (gregarious behavior), the result of reproductive processes, the daily or seasonal influence of climatic fluctuations, the response of the population to local differences in the nature of the biotope.

In plants and primitive aquatic invertebrates, the degree of aggregation is inversely proportional to the mobility of reproductive forms (spores, seeds, propagules, etc.).

II.4. Population regulation

II.4.1. Concept of density dependence

We have already emphasized that one of the most remarkable characteristics of natural populations is their relative stability. Even if they exhibit cyclical or aperiodic fluctuations, the numbers of animal or plant populations rarely undergo considerable amplitude variations - say greater than a factor of ten - and in any case oscillate in most cases around a average value which is the limiting capacity of the medium. There are, however, some exceptions to this observation. These concern species introduced artificially by man into environments which are ecologically favorable to them, or on the contrary species with declining populations (most of the time due to ecological disturbances induced by man or by following its direct action on the species concerned, through fishing or hunting); finally, the human population itself which is experiencing a demographic explosion with already catastrophic consequences. We therefore come to wonder by what ecological mechanisms this stability of natural populations is ensured. To interpret the cause of variations in the size of a population over time, it is necessary to understand how birth and death rates are affected according to the density of the population considered, but also according to fluctuations in value presented by the limiting ecological factors specific to the ecosystem to which the species is dependent. In poorly evolved ecological systems, therefore poorly diversified, where abiotic factors present significant variations (cold, drought, flooding, pollution, etc.), the regulation of population numbers is carried out by these physicochemical factors.

In evolved, highly differentiated and diverse ecosystems; where fluctuations in physicochemical factors are of low amplitude, population control is ensured by biotic factors.

Finally, note that in any biocenosis, the tendency of natural evolution leads populations - through the play of selection phenomena - to develop a self-regulation system because, as Odum (1959) *in* [1] very aptly pointed out, overpopulation is not in the interest of any living species.

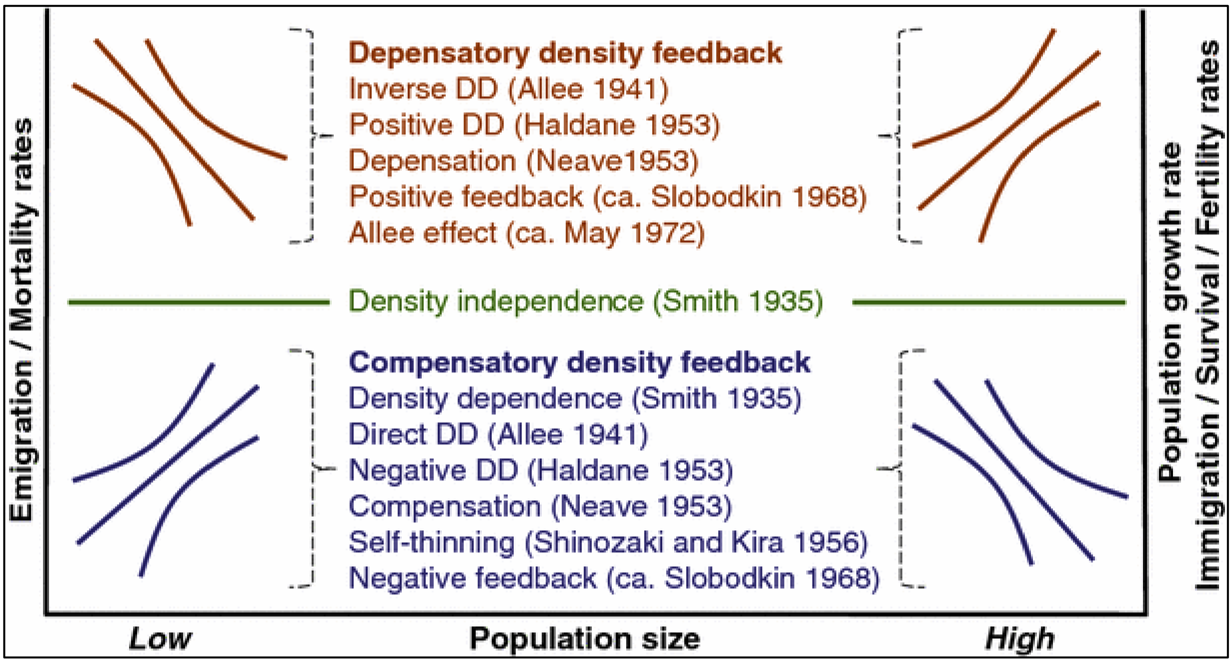


Figure 13. Density dependence.

(https://www.google.com/url?sa=i&url=https%3A%2F%2Flink.springer.com%2Farticle%2F10.1007%2Fs00442-012-2347
3&psig=AOvVaw3GA7eqXmPQxoBShwXiJjlx&ust=1728933135958000&source=images&cd=vfe&opi=89
78449&ved=0CBQQjRxqFwoTCJDEv4GIjIkDFQAAAAAdAAAAABAE).

II.4.2. Density-independent and density-dependent factors

It is particularly interesting, in demoecology, to analyze the action of ecological factors through the concept of density-dependence. Whatever their nature, it is always possible to divide ecological factors into one of the following two categories [15] :

- Factors independent of density.

- Density dependent factors.

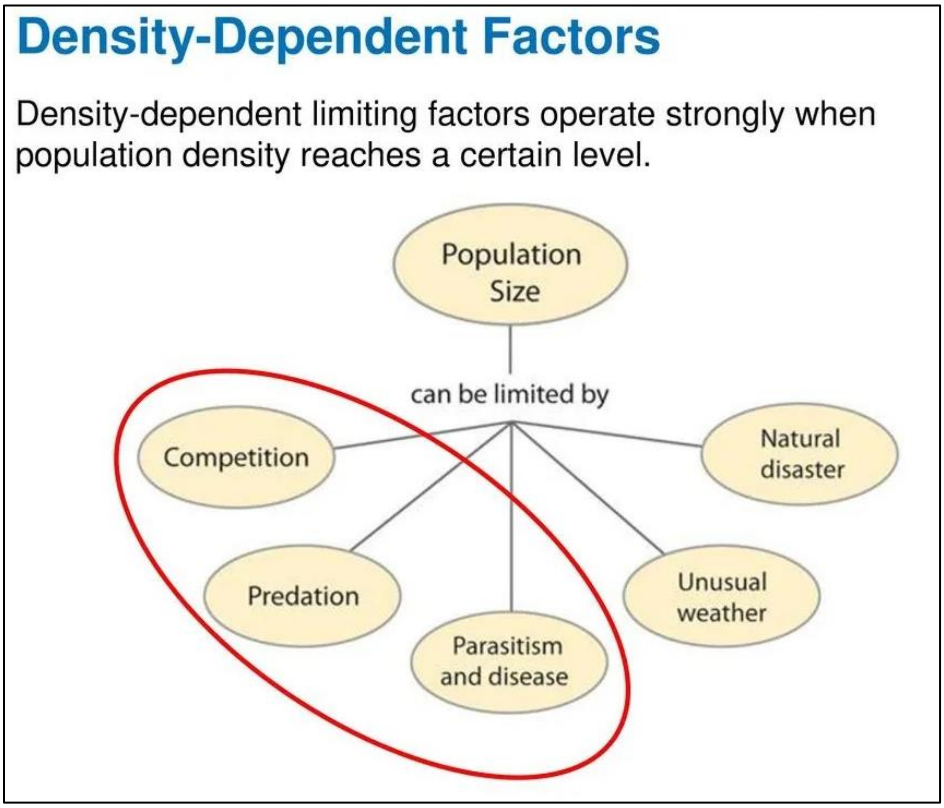


Figure 14. Density-dependent limiting factor: (https://inspiritvr.com/effect-of-density-of-populations-study-guide/).

II.4.3. Influence of density-independent factors

Edapho-climatic factors can play a key role in fluctuations in the abundance of many species of terrestrial invertebrates, in particular. The same is true for various other physicochemical factors specific to aquatic ecosystems.

II.4.4. Influence of density-dependent factors

Density-dependent factors play a fundamental role in determining population fluctuations. The main biotic factors, whose influence is decisive on population dynamics, are competition, predation, parasitism and diseases [6-9].

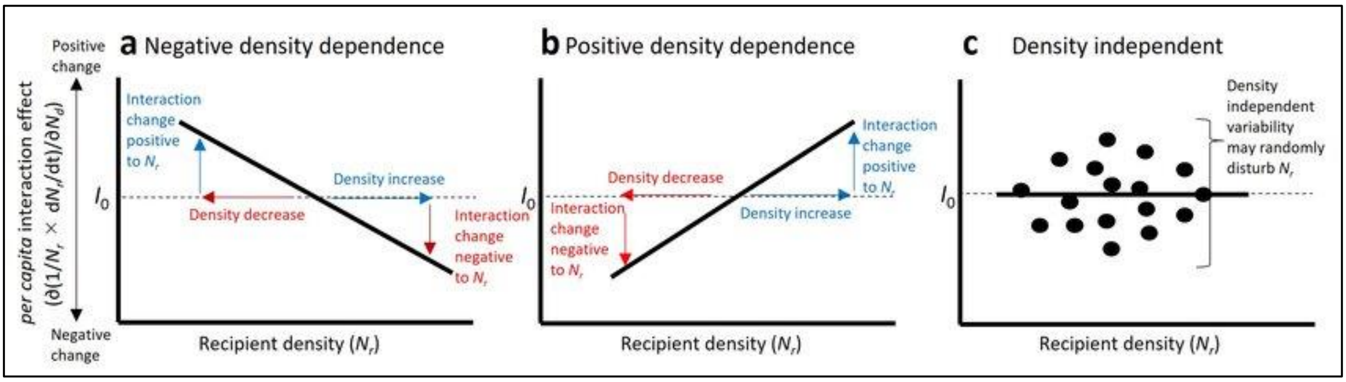


Figure 15. Density-dependent/dependent factor: (https://www.researchgate.net/publication/356935273_Multifaceted_effects_of_variable_biotic_interactions_on_population_stability_in_complex_interaction_webs/figures?lo=1&utm_source=google&utm_medium=organic).

Chapter III. Structure and organization of people and biocoenoses

III. Structure and organization of people and biocoenoses

III.1. Concept of population and biocenosis

In their natural habitat, most populations are in contact with a considerable number of other species, generally several hundred or even several thousand, which constitute a particular biocoenosis. If among the multiple interactions taking place between these numerous species, the vast majority have at most only a secondary effect on the populations concerned, some of them on the contrary play an essential role. Understanding the structure and functioning of ecosystems involves, as a preliminary step, a good knowledge of the organization of their respective biocoenosis. The study of the organization of a biocoenosis requires answering many questions: how many different species does it contain, what does the relative abundance of the species mean, what factors determine the total number of species present in a given biotope, how do the different populations of these various species fit together to constitute the entire biocoenosis. Groups of neighboring species belonging to the same systematic group, which exploit within an ecosystem – sometimes in very subtle ways – the same category of resources, constitute "elementary" populations called guilds.

III.2. Organization of populations

Generally speaking, we can say that the factors likely to intervene in the organization of populations are the same as those mentioned in connection with the determination of their specific diversity.

III.3. Biodiversity

The term biodiversity is a neologism that appeared towards the end of the 1970s to designate biological diversity, that is to say the diversity of life and therefore of the living beings which populate the biosphere. It was widely disseminated, even trivialized following the international convention intended to safeguard biological diversity which was promulgated at the United Nations conference in Rio on environment and development in June 1992.

"Biological diversity refers to the variety and variability among diverse forms of life and in the ecological complexes within which they occur."

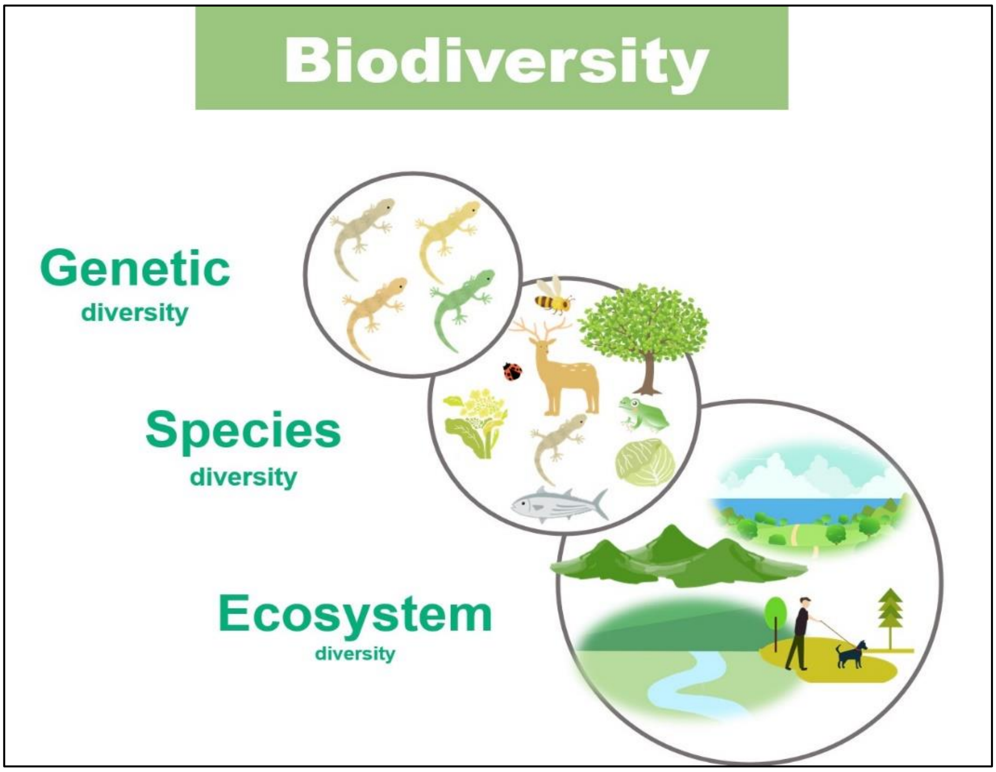


Figure 16. Biological diversity.
(https://cocreationproject.jp/en/activity/biodiversity-en/).

III.4. Specific richeness

It ultimately represents one of the fundamental parameters characteristic of a population and represents the most frequently used measure of its biodiversity.

We distinguish a total richness, S, which is the total number of species that the population considered contains in a given ecosystem; the total richness of a biocoenosis corresponds to all of the species that comprise it.

III.5. Influence of main ecological parameters on the importance of biodiversity

There are considerable variations in the total richness of populations and biocoenoses, with many ecological factors and other environmental parameters being able to influence the composition of another community [15] :

III.5.1. Relationship with latitude

We generally see that species richness is maximum in equatorial populations, and minimum in those of Arctic ecosystems. The general tendency to increase specific richness and ecological diversity when we move from subpolar or orophilic biocoenoses to those located at lower latitudes or altitudes, constitutes one of the fundamental data of biogeography.

In reality, latitude does not act directly but through favorable climatic factors such as temperature and rainfall. This explains why the decrease in specific richness does not absolutely follow the increase in latitude.

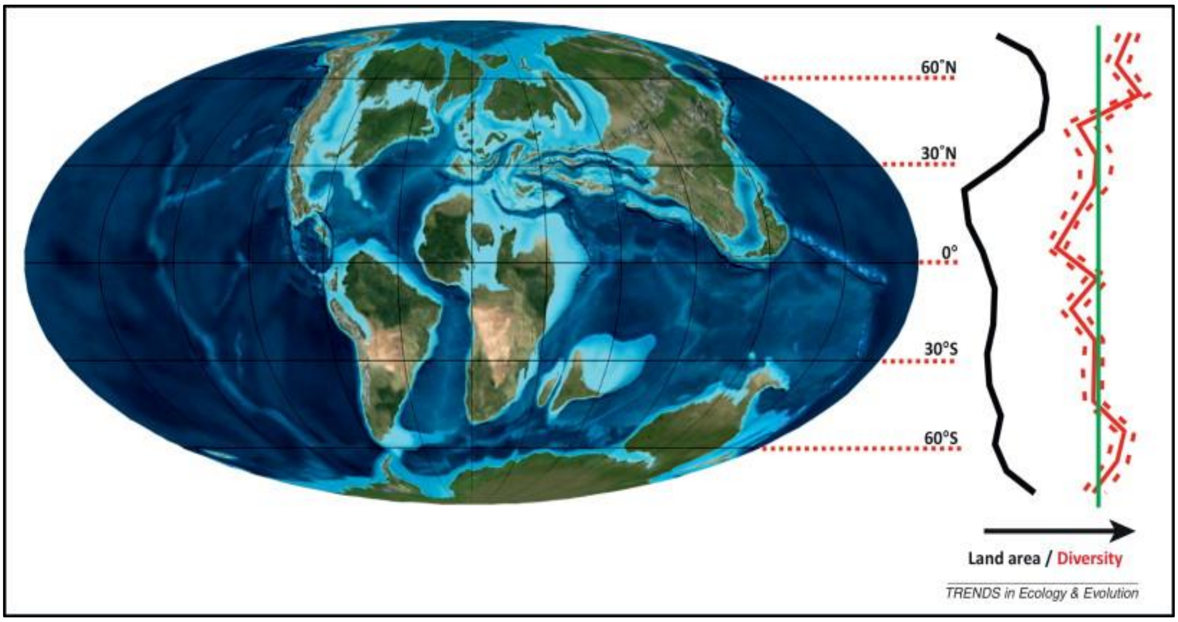


Figure 17. The latitudinal biodiversity gradient.
(https://www.sciencedirect.com/science/article/pii/S0169534713002358).

III.5.2. Relationship with altitude

In general, it follows from this similarity of latitudinal and altitudinal climatological conditions a homology between the types of ecosystems that we encounter in the continental biosphere when we move from the equator towards the poles or when we rise in altitude at a given latitude.

III.6. Structure and organization of the biocenosis

The description of the structure and the understanding of the organization of continental biocoenoses therefore involve, as a preliminary step, the characterization of the adaptive forms of plants, their ecomorphology being conditioned by their spatial position in the biotope and the nature of their habitat.

III.6.1. Structure of biocenoses

The physiognomy of terrestrial biocenoses is primarily conditioned by the specific composition and structure of the plant community (phytocenosis) which is specific to it. Each phytocenosis can be characterized by a particular vertical and horizontal structure as well as by the relative proportion of the various plant forms which are involved in the floristic composition.

-Vertical stratification of phytocenoses

a) Aerial stratification

It has four main forest strata: tree, shrub, herbaceous and muscinal (= cryptogamic). The tree stratum is often subdivided into sub-strata, the upper sub-stratum, composed of large trees constituting the canopy, whose heights vary greatly depending on the phytocenosis considered (20 to 30 m in deciduous, temperate forests, 30 to 45 m in tropical forests, 100 m in temperate coniferous rainforests of western North America). The lower substratum, made up of smaller trees, is between 10 and 20 m. The shrub layer, made up of shrubs and shrubs of size varying from 1 to 10 m, is often subdivided into shrub layer in the strict sense (shrubs of 3 to 10 m) and sub-shrub layer, made up of woody plants of 1 3 m high. The herbaceous layer, of mixed composition, includes tree seedlings and herbaceous plants of the undergrowth. Finally, the moss stratum, occupying the first decimeter of the soil surface, is made up of mosses, lichens and fungi [15].

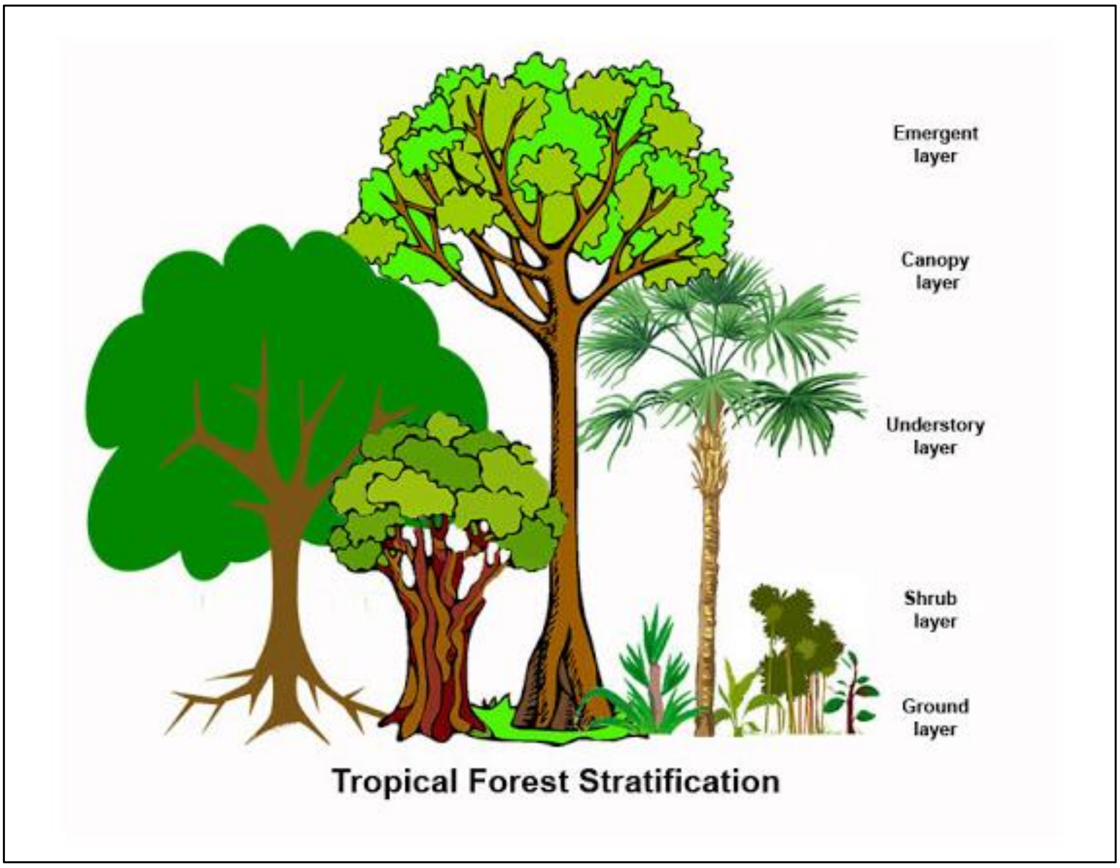


Figure 18. Aerial stratification.
(https://byjus.com/question-answer/presence-of-plants-arranged-into-well-defined-vertical-layers-depending-on-height-can-be-seen-7/).

b) Horizontal structure of phytocenoses

It should not be confused with the nature of their floristic composition and concerns the distribution of individuals on the surface of the soil. This presents a heterogeneity of varying importance but always marked (except in crops), with contagious type distributions very often predominating.

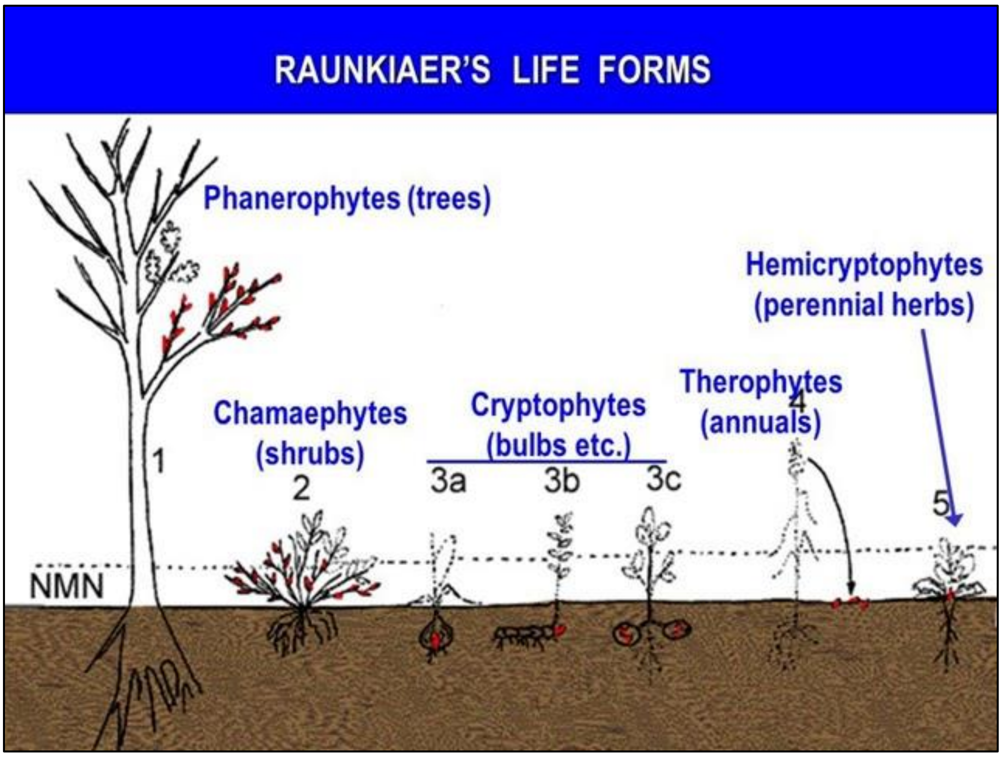


Figure 19. Horizontal structure.
(https://www.youtube.com/watch?v=dBWbutqxIqM).

III.6.2. Organization of biocenoses

Ecologists have tried to describe with ever-increasing precision the composition of biocoenoses in order to analyze their organization. As the description of the entire biocoenosis represents a considerable task, it appeared that the understanding of its organization could be facilitated by limiting its analysis to the study of the phytocenosis; plants in fact have the advantage of being fixed and therefore lending themselves easily to statistical enumerations. In reality, we can limit ourselves to the analysis of the population of phanerogams, which is predominant in most phytocoenoses and whose study is the easiest.

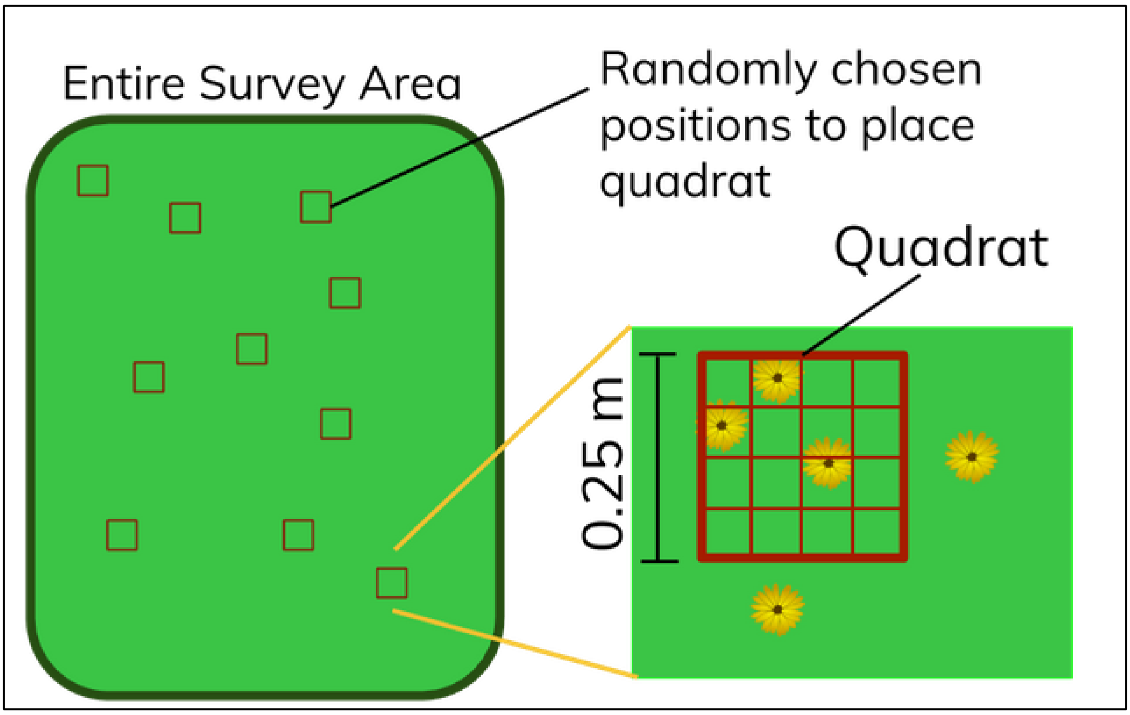


Figure 20. Quadrat sampling. (https://senecalearning.com/en-GB/revision-notes/a-level/biology/aqa/7-4-4-investigating-population-size).

Chapter IV : Interactions within the biotic component of the biocenosis

IV. Interactions within the biotic component of the biocenosis

IV.1. Negative interactions

IV.1.1. Competition

The term competition designates a situation in which a resource is not available in sufficient quantity either for each individual of a population of the same species (this is then intraspecific competition) or for two populations of species. different (interspecific competition).
The use of the resource by an individual or a species reduces its availability for the other individual or the other species, which will be affected in their growth or survival by the scarcity of this resource.

- ✓ **Intraspecific competition**

Its intensity depends on the density. It constitutes an essential population regulation process. When an essential resource is no longer available in sufficient quantity, the individuals who constitute the population concerned compete to obtain it. Access to light or water in plants, the search for food or the space necessary for nesting in animals constitute essential issues in intraspecific competition.

- ✓ **Interspecific competition**

This type of competition manifests itself when two different species use a common resource whose availability is limited (competition by exploitation) or if their populations hinder each other's access to the resource they need, even if it exists in superabundant quantity. (competition by interference).

Figure 21. Competition Within And Among Population.
(https://www.youtube.com/watch?v=sgvCuPoOOsU).

IV.1.2. Predation

Taken in its broadest meaning - food consumption - predation is the initial factor in the transfer of energy in biocenoses, it defines the links characterizing trophic chains and networks. Predation therefore constitutes an essential ecological process which also controls the populations constituting communities and their evolution.

IV.1.3. Parasitism

Relationship between two species of plants or animals in which one benefits at the expense of the other, sometimes without killing the host organism.

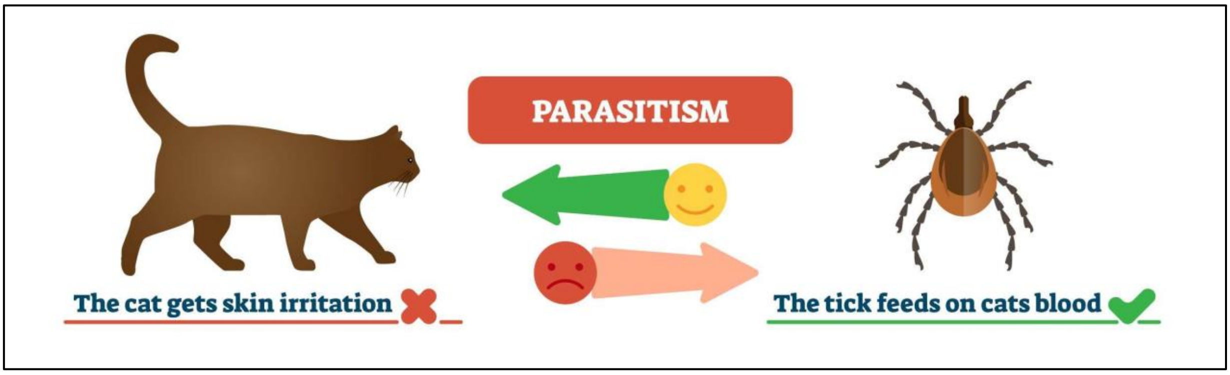


Figure 22. Parasitism.

IV.2. Interactions positives entre species

IV.2.1. Commensalism

It represents the simplest case of positive interaction and arguably the first evolutionary step toward developing mutually beneficial relationships. It is found both in aquatic environments and in terrestrial biocenoses. It is particularly common between a plant and a sessile animal or between a sessile animal and another mobile. However, it is also found between plants. In commensalism, the host does not benefit from the foreign organism to which it offers shelter and (or) food.

IV.2.2. Mutualism

Many living organisms can associate with each other and benefit from each other, even though they can develop independently under normal conditions. Thus, phanerogams exert a favorable effect on soil micro-organisms by releasing mineral and organic molecules from such substances and thanks to the root exsorptions of higher plants, a rhizosphere is thus formed, a particular zone of the soil in which exerts the influence of the roots. The latter release carbohydrates, amino acids, phenols, vitamins, enzymes, etc., whose action is favorable to the soil microflora.

IV.2.3. Symbiosis

It constitutes the most evolved form of associations between species. It is obligatory for the organizations that practice it. Here the two organisms are associated by both structural and functional links, the association being so close that symbiotic organisms generally cannot develop - or at least show the greatest difficulty in surviving - in the absence of their host.

Chapter V. Evolution of biocenoses

V. Evolution of biocenoses

V.1. Concept of succession

Ecological succession is the process by which the mix of species and habitat in an area changes over time. Gradually, these communities replace one another until a "climax community"—like a mature forest—is reached, or until a disturbance, like a fire, occurs. Ecological succession is a fundamental concept in ecology. The succession takes place due to changes in the physical environment and population of the species. The succession is mainly of two types: primary and secondary succession. The ecological succession occurs in the five stages : **nudation, invasion, competition and coaction, reaction and stabilization** [15].

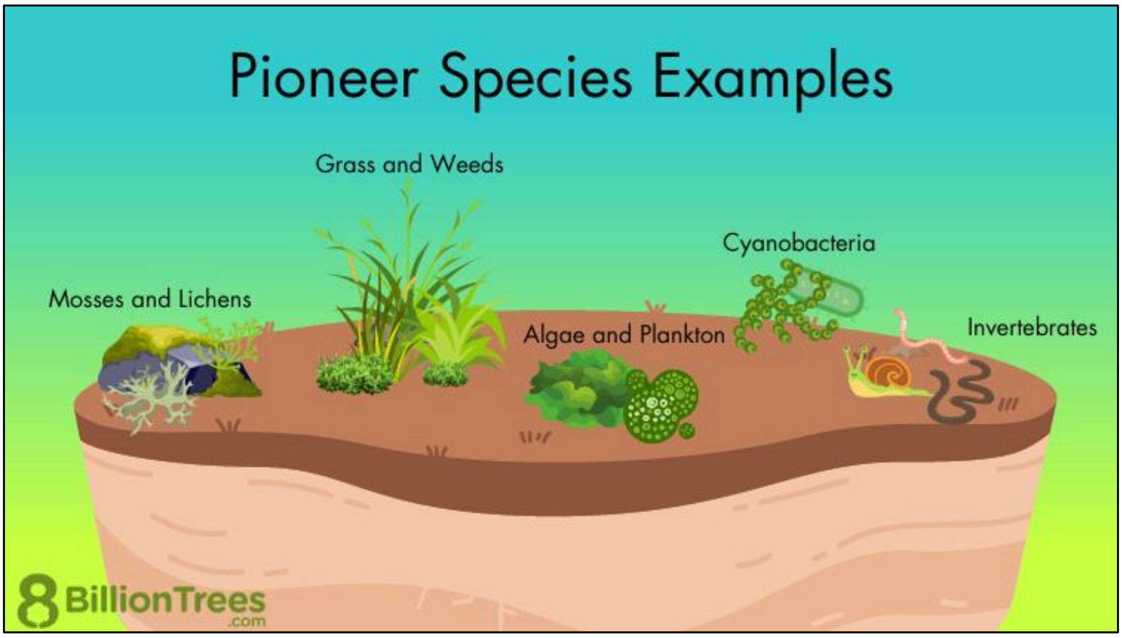


Figure 23. Pionner species.
(https://8billiontrees.com/trees/pioneer-species/).

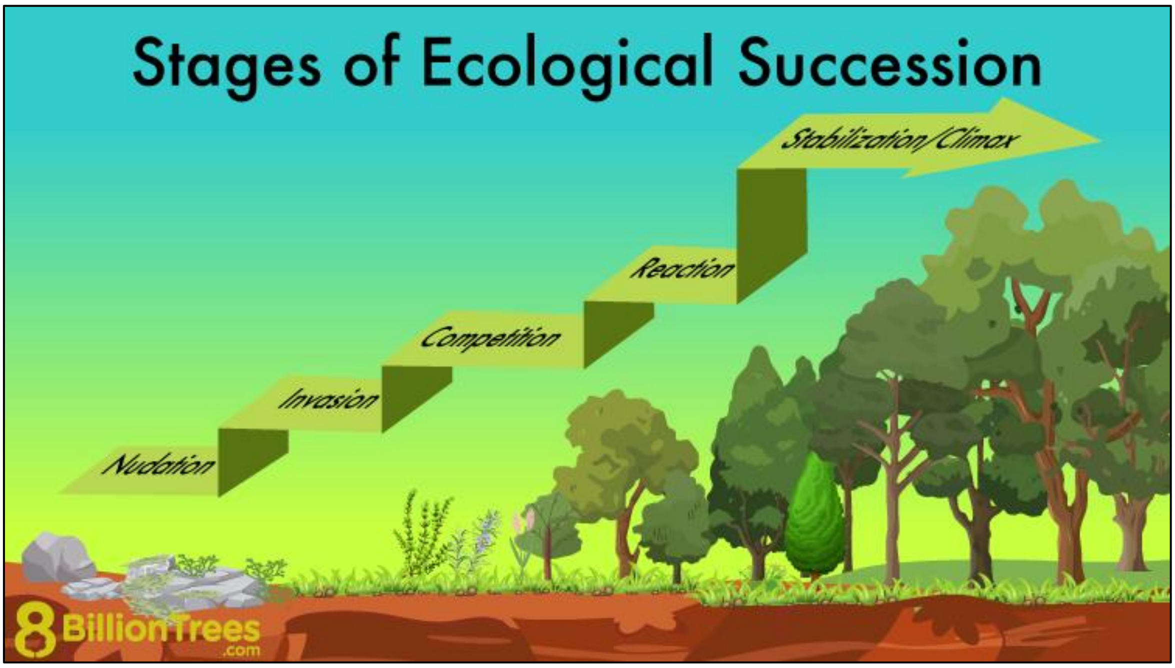


Figure 24. Concept of succession.
(https://8billiontrees.com/trees/pioneer-species/).

V.1.1. Type of succession

Successions can be classified according to various modalities. It is usual to distinguish between **autogenic and allogenic successions**. Autogenic successions come from a biotic process taking place within the ecosystem. They result from the development of a community on an initially disturbed biotope and its evolution over time towards an ecosystem whose structure and populations are increasingly complex [15].

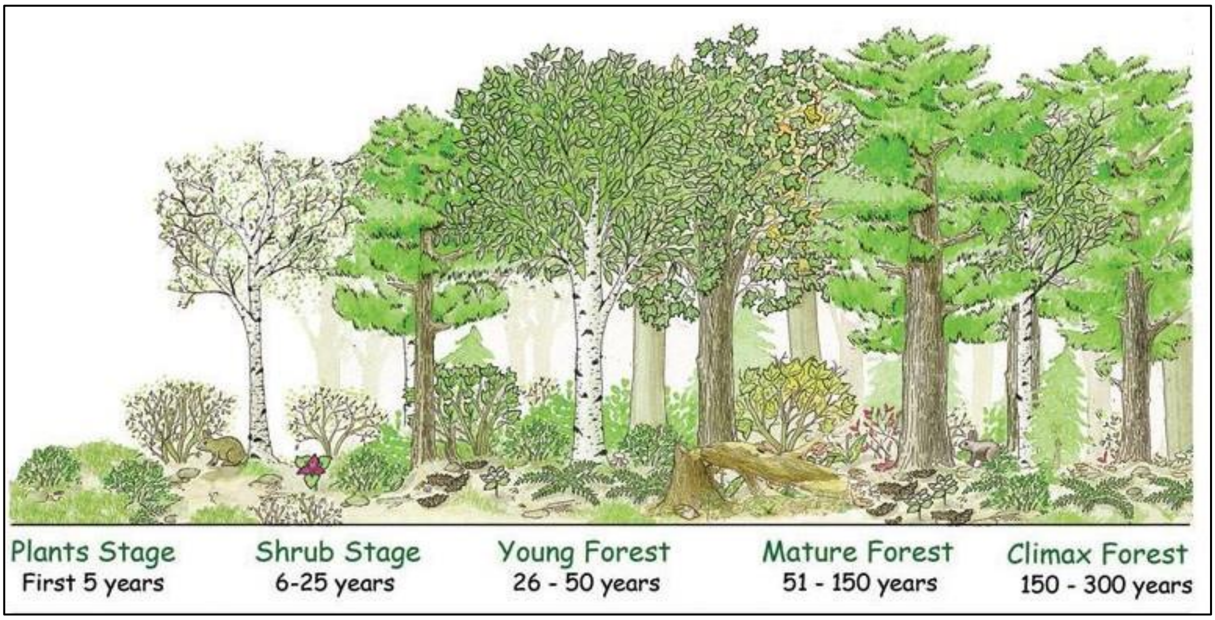


Figure 25. Example of progressive autogenic succession [1].

V.1.2. Successions and spatial gradient of biocoenoses: ecoclines

When an ecological factor presents a variation in intensity along a geographic gradient, the changes observed in the structure and composition of biocoenoses depending on the factor considered constitute an ecocline [15].

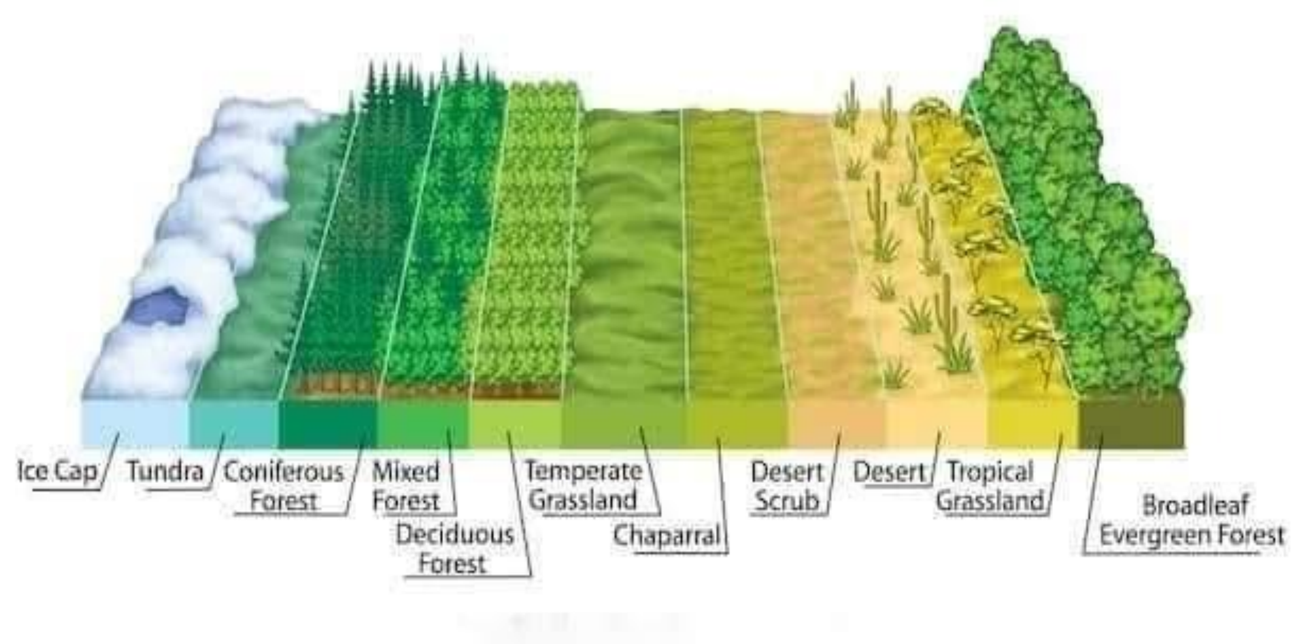


Figure 26. Ecocline simply means.

V.2. Strategies demographiques

V.2.1. Concept of adaptive strategy

During succession, the evolution of ecosystems responds to a set of laws of very general, if not universal, scope:

- Acquisition of increasingly effective homeostatic mechanisms intended to protect and perpetuate climax biocenoses;
- Development of resistance of biocenoses to any modification of their structure as opposed to the immigration of exogenous species and the emigration of species specific to them, with the corollary of the creation of a closed community at the end of succession , this spatial stability limiting the loss of resources;
- Modification of the structure and composition of the biocenosis throughout the successional gradient, characterized by the dominance of small, prolific species, which present significant fluctuations in abundance within the stages the stages pioneers, and at the climax by that of large species, not very fertile and whose populations are stable.

One of the most general characteristics of ecological successions is that there gradually occurs during their evolution a "substitution of a quality strategy (highly organized and energy-efficient system) in the developed systems for a quantity strategy (explosive growth of wasting populations of propagules, and therefore energy) in pioneer ecosystems.

V.2.2. Stratégies démographiques (r/k)

R-strategists are typically small, reproduce rapidly, and have a high death rate at a young age. They thrive in volatile environments. Conversely, K-strategists are often larger organisms with a slower reproductive rate but higher offspring survival; they do well in predictable, stable habitats. (R vs K strategists examples : You can see r- and K-selected strategies clearly by looking at different organisms within a phylogenetic group, such as the mammals. For example, elephants are highly K-selected, whereas mice are much more r-selected. Among the fishes, most, like the salmon, are r-selected) [10-15].

	r Unstable environment, density independent	***K*** Stable environment, density dependent interactions
Organism size	Small	Large
Energy used to make each individual	Low	High
# Offspring produced	Many	Few
Timing of maturation	Early	Late (with much parental care)
Life expectancy	Short	Long
Lifetime reproductive events	One	More than one
Survivorship curve	Type III	Type I or II

Table 1. R Vs. K Strategy.

Chapter VI. The main continental biomes of biosphere

VI. the main continental biomes of biosphere

Scientists classify biomes into five main types : aquatic, desert, forest, grassland and tundra. The main reason for classifying the biosphere into biomes is to highlight the importance of physical geography on communities of living organisms [16].

There are five major types of biomes: aquatic, grassland, forest, desert, and tundra, though some of these biomes can be further divided into more specific categories, such as freshwater, marine, savanna, tropical rainforest, temperate rainforest, and taiga.

VI.1. Biomes

A biome is a large community of plant and animal wildlife adapted to a specific type of location and climate. I explain the geographical and climatic features of all the major terrestrial biomes, including: polar, tundra, boreal forest, temperate forest, tropical rainforest, grassland, savanna, desert, and freshwater ecosystems (including lakes, rivers and wetlands).

The biosphere is divided up into a number of biomes. Biomes are regions with similar climate and geography. The key factors determining climate are average annual precipitation (rainfall) and temperature. These factors, in turn, depend on the geography of the region, such as the latitude and altitude of the region, and mountainous barriers. The specific conditions of biomes determine the plant and animal life found within them. The communities of plants, animals and soil organisms in a particular biome are collectively referred to as an ecosystem. Biomes can be aquatic or terrestrial [15, 17].

VI.1.1. The Biosphere

The biosphere is divided into a hierarchy of vaguely defined geographical regions, according to size. The largest of these is the "biogeographical realm" or "ecozone". According to the WWF classification, these are 8 of these realms. [16, 17].

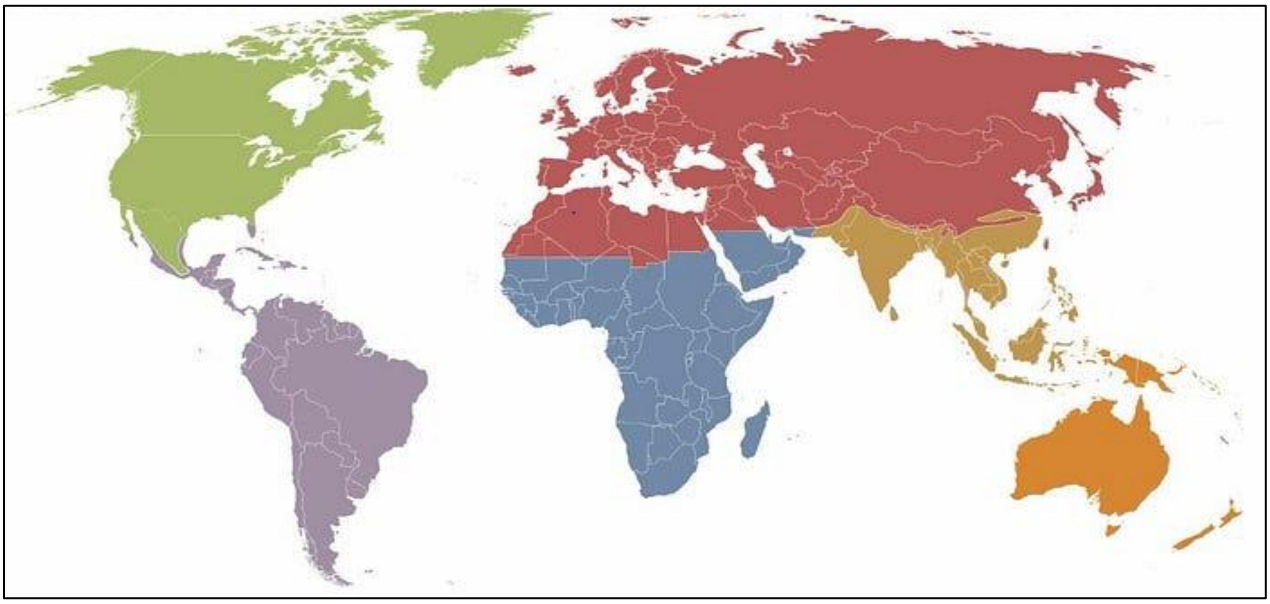


Figure 27. Map showing 6 of the 8 Main Biogeographical Realms (Ecozones). Green = Nearctic; red = Palearctic; purple = Neotropic; blue = Afrotropic; brown = Indomalaya; orange = Australasia. Not shown are the Antarctic Realm and the Oceania Realm (contains no continental land mass but includes Polynesia, Micronesia, and the Fijian Islands).
(Image: © Carol (CC BY-SA 3.0).

VI.1.2. The 8 Biogeographical Realms

- Palearctic (54m sq km) — most of Eurasia and North Africa.
- Nearctic (22.9m sq km) — most of North America.
- Afrotropic (22m sq km) — Trans-Saharan Africa and Arabia.
- Neotropic (19m sq km) — most of South America, Central America, and the Caribbean.
- Australasia (7m sq km) — Australia, New Guinea, New Zealand, and neighbouring islands.
- Indomalaya (7.5m sq km) — Indian subcontinent, Southeast Asia, southern China.
- Oceania (1m sq km) — Polynesia, Micronesia, the Fijian Islands.
- Antarctic (14m sq km) — Antarctica.

VI.1.3. The 9 Most Important Biomes

We profile nine biomes: ice cap, tundra, taiga, temperate forest, tropical rainforest, grassland, savanna, desert, and freshwater (lakes, rivers and wetlands) [18].

a. Polar Ice Cap Biome

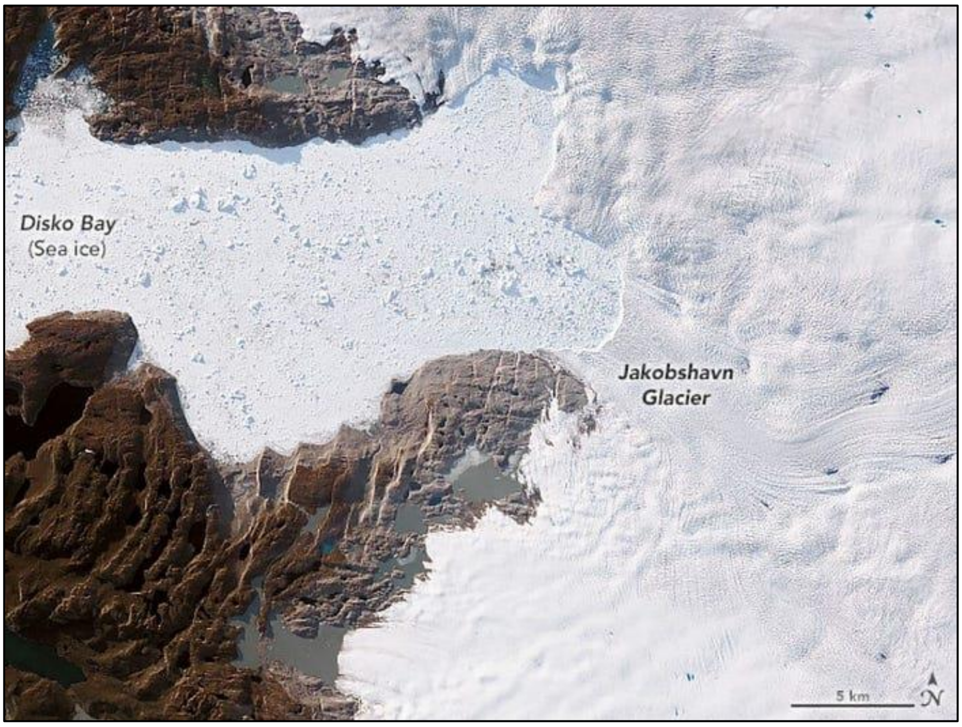


Figure 28. Jakobshavn Glacier in western Greenland is notorious for being the world's fastest-moving glacier. It discharges a huge amount of ice (sea ice) into the Disko Bay area, which has implications for rising sea levels.
(Photo: © NASA Satellite image, June 2019).

An ice cap is a covering of ice over a large area of land — usually less than 50,000 sq km. Larger ice caps are known as ice sheets, of which there are two in the world — one covering Antarctica, the other covering Greenland. All ice environments form part of the cryosphere, the sub-system of Planet Earth that consists of solid water. The main function of the cryosphere is to help regulate Earth's climate system by absorbing heat from the equator and distributing cold water around the world, via deep-water currents [19].

- Location

The two main areas with ice cap climates are Greenland and Antarctica, both of which have vast deserts of snow and ice. The Greenland ice sheet occupies an area of 1,710,000 square kilometres (660,000 sq mi). This excludes its coastline, which is tundra. By comparison the Antarctic ice sheet covers an area of 14 million square kilometres (5.4 million sq mi).
In addition, a large portion of the Arctic Ocean near the North Pole remains frozen 365 days of the year, which in practice gives it an ice cap climate [20].

-Climate

The ice cap climate is famous for its freezing polar conditions in which no mean monthly temperature exceeds 0 ºC (32 ºF). During the coldest months, mean temperatures range between minus 30 and minus 55 ºC (minus 22 to minus 67 ºF). The biome's low temperature is mainly due to the angle of the Sun, which is very low in the sky, forcing the sun's energy to pass through more atmosphere. This means the sunlight that reaches the surface contains less energy than at the equator. Much of the sunlight is also reflected back into space.

The Arctic used to be noted for long, cold winters and short, cool summers, although this is changing due to rising temperatures throughout the region. Precipitation is low, no more than 200mm (7.5 in) per year, mostly in the form of snow. Some of the Arctic is covered by ice (sea ice or glacial ice) all year-round, with nearly all areas undergoing long periods with some form of ice on the ground.

The Greenland ice sheet is between 2 km (1.2 mi) and 3 km (1.9 mi) thick. However, due to the amount of ocean water in the circumpolar region (whose temperature can never fall below −2 ºC /28 ºF), the Arctic is significantly warmer than Antarctica, which is a continental land mass. (9)

Antarctica is really like a cold desert, due to its low level of precipitation (166 mm/ 6.5 in), which is exclusively snow. In coastal regions, it rises to about 200 mm. It is noted above all for its extreme cold, especially in higher areas where temperatures typically decrease 1ºC for every 100 m increase in height. It's worth noting that Antarctica is the world's highest continent, with an average land height of 2,300 meters (7,475 feet). Its cold is also exacerbated by its high albedo, which reflects most sunlight back into space. The continent also experiences hurricane force winds, up to 200 mph.

Antarctic ice averages 2.5 km in thickness and can go up to 5 km deep. Antarctica contains 90 percent of the world's stock of ice and more than 70 percent of its freshwater. Much of the ground underneath the ice is below sea level, but this is due not to its lack of elevation but rather the weight of the ice itself. If the ice were to melt, the ground would rise back up again.

During the winter months, the waters of the Southern Ocean surrounding Antarctica, turns to ice. This sea ice nearly doubles the size of the continent [20].

-Plants

Ice caps are usually covered by a permanent layer of ice and therefore have no trees, plants or shrubs to speak of, and very few flowering plants.

-Animals

There is some limited animal life (e.g. polar bears) on the ice cap, usually found near the ocean edges where seals breed. The polar climate is very inhospitable to humans, although a number of scientific research stations are located in both Greenland and Antarctica, such as the facilities operated by the British Antarctic Survey.

The main exception to the lack of animals is Antarctica's penguin kingdom that comes ashore to breed in their millions. However, although they breed on land, their energy and food come from the Southern Ocean, so they are classified as part of the marine ecosystem.

The Southern Ocean is exceedingly rich in life, due in part to the upwellings of the deep-water thermohaline circulation, bringing nutrition up from the depths. Although phytoplankton are seen now in the Arctic, far more of these marine drifters are found in the Southern Ocean, where they serve as food for krill who occupy the trophic level above them in the marine food chain. Krill in turn feed whales and many other species. Returning to the penguins, these creatures are an important food source for leopard seals and killer whales.

-Effects of Climate Change on Ice Cap Biomes

Arctic sea ice is melting rapidly, as is the ice sheet in Greenland. This is due to record air temperatures in the Northern Hemisphere. Antarctica, too, is experiencing record-breaking temperatures which, together with shifting wind patterns, are believed to be causing rapid melting of ice in both West and East Antarctica. 10 The two giant West Antarctic glaciers – Thwaites and Pine Island – are seen as potential climate tipping points that might destabilize the entire West Antarctic Ice Sheet, triggering major sea level rise around the world.

b. Tundra Biome

The word tundra comes from the Finnish word 'tunturi', meaning 'treeless plain.' The tundra biome is best known for its cold, driving winds and cold temperatures. It's also noted for its sub-surface store of permanently frozen soil, or 'permafrost', which prevents the growth of trees and most other shrubs, giving tundra its distinctive barren and windswept appearance [21].

-Location

Nearly all tundra is found in the Northern Hemisphere, although some tracts occur in the Antarctic, and in high altitude Alpine areas around the world. In total it is thought to cover up to 20 percent of the Earth's land surface, although estimates vary according to different interpretations of the tundra biome.

-NOTE: Permafrost contains soil, silt, sand, gravel, clay, and small particles of rock, all bound together by frozen water (ice). Upper layers usually contain large amounts of semi-decomposed vegetation and animal material. Lower levels contain soils made up mostly of minerals. The layer of earth that sits on top of the permafrost — only 15 centimeters (6 inches) thick in colder areas, several meters thick in warmer areas — only freezes during the cold winter months but thaws during the spring and summer. Permafrost constitutes one of Earth's largest reservoirs of carbon. Were it to thaw, an enormous amount of carbon dioxide would enter the atmosphere.

In the Northern Hemisphere, tundra is found in the Arctic north of the boreal forest or taiga belt along the circumpolar coasts of Alaska, Canada and Siberia.

In the Southern Hemisphere, it occurs on the Antarctic Peninsula as well as on several outlying islands, including South Georgia, the South Sandwich Islands and the Kerguelen Islands. It is also found on the Auckland Islands, Antipodes Islands, Bounty Islands, and Campbell Islands of New Zealand, and Macquarie Island of Australia.

Alpine tundra occurs above the timberline on high altitude mountain summits, slopes, and ridges in ecoregions around the world. For example, in the North American Cordillera, the Andes of South America, the Alps and Pyrenees of Europe, the Eastern Rift mountains of Africa, and the Himalayas and Qinghai-Tibetan Plateau in Asia.

-Climate

The Tundra biome is characterized by extremely low temperatures and little rainfall (less than 250mm/ 10 inches annually). Winters are long with January temperatures averaging from minus 20° to minus 30°C (minus 4° to minus 22°F). Summers are short (6–12 weeks). Until the 1990s, summer temperatures rarely exceeded 50°F (10°C), with just enough heat to thaw the surface of the ground. Today, in some parts of the Arctic at least, temperatures have risen by 3–4°C (5.4 to 7.2°F). Scientists have calculated they are higher now than they have been for 44,000 years, perhaps even for 120,000 years. (11) As a result, in some areas, the surface rarely freezes even in winter and remains soggy all year from melted snow and rain.

-Plants

The soil of the tundra biome typically lacks nitrogen and phosphorus — two important elements for plant growth. Plants therefore tend to be small or stunted and makes growth is slow. Most plants reproduce by budding and division rather than flowering. Also, the growing season tends to be short, lasting about 60 days. All tundra plants have adapted to driving winds and group together to help each other resist the cold temperatures. They have also adapted so that they

need only a small amount of water to germinate and grow, and in addition, have developed the ability to perform photosynthesis at low temperatures and in low light.
In total, there are roughly 1,700 plant species in the Arctic and Subarctic tundra biome and around 400 types of flowers. They include: arctic moss, Moss Campion, Caribou moss, crustose and foliose lichens, saxifrage, liverworts, willow shrubs and other small plants. Grasses include cotton grass and Alpine Blue grass. Tundra flowers include Bearberry, marsh marigold, Pasque flower and Labrador Tea flower. Alpine tundra plants also include tussock grasses, dwarf trees, small-leafed shrubs, and meadow plants.

-Animals

The apex predator of the tundra is the polar bear, whose food sources include summer berries and eggs, as well as seals, walruses, and trapped beluga whales. Other predators, like wolves and foxes, survive on caribou, lemmings, voles, and arctic hares. At the bottom of the food web, insects, such as moths, grasshoppers, mosquitoes, and other flies, provide food for migratory birds, including: snow buntings, loons, sandpipers, snow birds, terns and several species of gulls. In the warmer Alpine tundra biome, animals include elk, mountain goats, sheep, pikas and marmots, as well as insects like grasshoppers, butterflies, springtails and beetles.

-Effects of Climate Change on Tundra Biomes

One of the biggest effects of global warming on Tundra is permafrost thaw caused by the abnormally high temperatures. Scientists calculate that the amount of carbon locked into the permafrost is about twice that in the atmosphere. Which means that if permafrost thaw ever reached a tipping point and became irreversible, temperatures would skyrocket [22].

c. Taiga Biome (Boreal Forest)

Taiga, known in Canada and Alaska as boreal forest, is the largest land biome on the planet and is famous for its coniferous forests consisting mostly of pines, spruces, and larches [23].

Figure 29. Boreal forest, Alaska. There is little rainfall in the boreal biome. Precipitation comes in the form of fog and snow, with a little rain during the summer months.
(Photo: Public Domain).

-Location

It is found in a band around the Northern Hemisphere sandwiched between the tundra in the north and either temperate grassland or deciduous forest in the south. It covers about 17 million square kilometres (6.6 million square miles) of the Earth's land area [24].
It covers most of inland Canada, Alaska, and parts of the northern United States. In Europe, taiga covers part of the Scottish Highlands; the coastal areas of Iceland; much of Norway; most of Sweden and Finland; a swathe of Russia (including a vast area of Siberia) all the way from Karelia in the west to the Pacific Ocean in the East; plus northern Kazakhstan, northern Mongolia, and northern Japan. In addition, it is found at high altitudes in the more temperate latitudes, such as the mountainous western area of North America.
Tree species and summer temperatures vary, however. For example, the boreal forests of North America contain mostly spruces; the Scandinavian taiga comprises a mixture of pines, spruce, and birch trees, the same as the Russian taiga, while the Eastern Siberian forests are mainly larch.

-Climate

The taiga biome can be colder as well as warmer and wetter than tundra. Generally, taiga forests experience long, cold winters (8–10 months), and short, mild, humid summers (typically 1–3

months but never more than 4 months). Winter days are short and very cold. The lowest recorded temperatures in the Northern Hemisphere were recorded in the Siberian taiga.
In general, the taiga has a subarctic climate with large seasonal variations in temperature. At its coldest, winter averages between −6 °C (21 °F) and −50 °C (−58 °F), while summer averages 10 °C (50 °F) or higher. Like the tundra, taiga also has permafrost in parts. Discontinuous permafrost is seen in areas with average temperatures below freezing (0 °C; 32 °F). Within the Arctic Circle, there is midnight sun in mid-summer.
In the south and west of the Eurasian taiga, the summers are warm and wet and last longer, while average annual temperatures are higher, sometimes merging into those of the deciduous forest or grassland biomes.
Fires are a relatively common occurrence in the taiga during the summer. They help the biome to regenerate by consuming dead wood and biomass, clearing out the tree canopies, and making room for new growth, which sunlight can now invigorate on the forest floor.
Precipitation in the taiga ecozone is relatively low throughout the year. Annual rainfall equivalent is 200–750 mm (8–30 inches), mostly as rain during the summer, but snow in winter. The ground may remain carpeted with snow for as long as nine months in the northernmost areas.
The growing season, when flowers and plants come alive, is between 80 and 150 days except in the extreme north where it averages 50–70 days, and in coastal areas of Scandinavia and Finland where it averages 145–180 days [25].

-Soil

Soils in the taiga are usually quite thin and nutrient-poor due to the cold, which stunts all metabolic development. The soil is acidic because of acids from falling evergreen pine needles, so the forest floor has only lichens and mosses growing on it, with few fungi to speed up decomposition and enrich the soil with organic content, as in deciduous forests.

-Plants

The taiga has a low diversity of plant life. Conifers (cone-bearing evergreen trees with needles) are the most prevalent type of tree. The thin needles with their waxy coating reduce water loss of the conifer through transpiration, and thus compensate for the difficulty in obtaining water from the frozen winter ground. But desiccation remains a problem. The design of the conifer's waxed needles also allows snow to slide off rather than snap branches with its weight.
Conifer species include pines, firs, spruces and larches. Occasionally deciduous species are present, including birch, oak, aspen, poplar, willow and rowan. The southernmost extremities of

the taiga may have trees such as maple, elm and lime scattered among the conifers, and there is sometimes a transition into a temperate mixed forest, as in eastern Canada.
The tree mix varies with climate and geography, so for example, in Scandinavia and western Russia, the Scots pine is a widespread species, while in the Eastern Canadian forests in the Laurentian Mountains and the northern Appalachian Mountains balsam firs dominate, while further north in the taiga of northern Quebec and Labrador, black spruce and tamarack larch are common.

-Animals

The boreal forest supports a reasonably limited diversity of animals due to the harshness of the climate. Canada's forests include 85 species of mammals, more than 100 species of fish, and around 32,000 species of insects. Insects play a vital role within the taiga ecosystem as pollinators, decomposers, and trophic levels within the food web. Many birds depend upon them for food during the summer months.
The taiga is a challenging biome for reptiles and amphibians, who depend on environmental conditions to regulate their body temperatures. The few species in the boreal forest include the common European adder, blue-spotted salamander, red-sided garter snake, northern two-lined salamander, Siberian salamander, wood frog, American and Canadian toads. Most hibernate underground in winter.
Fish in the freshwater ecosystems of the taiga must be able to adapt to life under ice-covered water. Species include northern pike, walleye, Alaska blackfish, white sucker, lake whitefish, pygmy whitefish, Arctic lamprey, several species of grayling, brook trout, chum salmon, and Siberian lake chub.
Several large herbivorous mammals can be found in the taiga, including the wood bison, which is native to northern Canada, and Alaska, and has been recently introduced into the Russian Far-East. Other herbivores include moose, reindeer and caribou. Some areas of the more southern taiga also contain elk (wapiti) and roe deer.
Smaller mammals include beaver, squirrel, porcupine, vole, ermine and moles, as well as the snowshoe and mountain hares. Some larger mammals, such as bears, eat heavily during the summer in order to gain weight. Then they hibernate during the winter.
Predatory mammals of the taiga include grizzly bears, wolves, lynx, stoat, weasel, sable, river otter, mink, wolverine, red fox, brown bear, American black bear, Asiatic black bear, and Siberian tiger [26].

Over 300 species of birds nest in the taiga, taking full advantage of the long summer days and abundance of insects found around the numerous bogs and ponds. Of these species only 30 remain for the winter. These either feed on carcasses or prey on live mammals. Species include, golden eagles, rough-legged buzzards, ravens, grouse and crossbills.

-Effects of Climate Change on Taiga/Boreal Forest Biomes

In 2019, Arctic wildfires in Siberia and northern parts of Russia destroyed 43,000 square kilometres (17,000 sq mi) of taiga. In Canada, 18,000 square km were lost, while in Alaska 9,700 square kilometres were destroyed. The Siberian fires alone released carbon emissions equivalent to Sweden's entire annual output of greenhouse gases, and resulted in a cloud of smoke greater than the entire surface area of the EU [26].

d. Temperate Forest Biome

Figure 30. Temperate forests in the Jura mountains, Switzerland have a moderate climate and precipitation is generally distributed evenly throughout the year. The canopy of a temperate forest consists mainly of broad-leaved trees. As you move closer to the polar regions, temperate forests give way to boreal forests. (Photo © Yann Vitasse/imaggeo.egu.eu).

Temperate forests consist of a wide mixture of deciduous broad-leaved trees that shed their leaves in autumn. (15) A mild climate combined with a rich diversity of plants, provides abundant food and habitats for a wide range of animals, birds and insects.

-Location

Most temperate forests are found between 40–60º north and south of the equator. Some of the best examples are the deciduous forests of eastern North America, Southern Europe, Central China and Russia's Far East.

-Climate

The climate of the temperate broadleaf forest biome is characterized by plentiful all year-round rainfall (up to 1500mm, 60 inches, annually), along with mild temperatures around 3–16 ºC (37–60 ºF), at least in the mid-latitudes. The biome has four well-defined seasons, caused by the tilt of the Earth's axis. During the year, the sun's rays strike different parts of the world more directly than others, resulting in varying temperatures, or seasons. In the temperate forest biome, this leads to warm summers and cool winters, although conditions vary somewhat around the world. For example, the southern edge of the zone tends to be more humid throughout the year.

-Deciduous Trees

Deciduous trees, the dominant trees in temperate woodlands, have leaves rather than pine needles, and they change with the seasons. In the summer their broad green leaves absorb sunlight which they turn into energy via the process of photosynthesis. As temperatures fall during the autumn, the green pigment in their leaves (chlorophyll) breaks down, revealing the brilliant oranges, reds and yellows, that we see at this time of the year. In winter, deciduous trees and plants enter a sort of stand-by state — it's too cold for them to prevent their leaves from freezing, so they simply shed them, and seal the spots where leaves were attached, with a protective cover. With the advent of warmer spring temperatures, they grow new leaves, and the cycle restarts.

-Forest Structure

Temperate deciduous forests typically have a 4-layer structure. The topmost layer is the 'canopy', consisting of tall mature trees standing 30–61m (100–200 ft) high (like oaks).

Below the canopy are three layers that make up the 'understory', standing about 9–15m (30–50 ft) shorter than the canopy. The upper section consists of shorter mature trees (like maples), saplings, and juvenile canopy layer trees awaiting an opening in the canopy, through which to rise. Next comes the shrub layer, consisting of low woody plants (mountain laurel, huckleberries, azaleas, hydrangeas, pussywillow, Japanese barberry, wayfaring tree, Russian almond, and tons more). Finally, there is the ground cover or herbaceous layer — the layer with the most variety (ferns, lichens and mosses).

In the Northern hemisphere, the tallest broadleaf trees include oaks, beeches, or birches. Coniferous trees, whose presence in the canopy earns the forest its 'mixed' status, include firs, pines, and spruces. In some parts of the North, conifers may actually be more dominant than the broadleaf species, as the taiga and the temperate deciduous forests overlap. In the Southern Hemisphere, unique species such as Eucalyptus and Nothofagus are prevalent [27].

-Soil

Falling leaves combined with damp conditions and plentiful fungi and bacteria, results in rapid decomposition of leaf litter, animal remains and other forest biomass. So, soil is typically high in nutrients with a high content of organic-rich humus.

-Animals

Animals in temperate deciduous forests must adapt to the changing seasons — the cold winters and hot summers. Some animals hibernate during the winter to escape the cold. Animals who do not hibernate must find other ways to hide, because when the forest loses its leaves, there is less cover in which to hide from predators.
Black bears are especially well adapted for the deciduous forest biome. They have thick coats to deal with the winter cold, long claws to help them climb trees (whose hollows provide fine shelter), and they eat almost anything. They also hibernate to avoid the struggle of finding food in the snowy winter. Other forest animals include: red foxes, white-tailed deer, raccoons, opossums, porcupines, squirrels, mice, frogs, lizards, as well as spiders, slugs and many other insects. Birds include: woodpeckers, cardinals, snowy owls, broad-winged hawks and more.

-Effects of Climate Change on Temperate Forest Biomes

The main effect of climate change on temperate forests is a gradual warming resulting from the migration of tropical-style temperatures away from the equator. This leads to a gradual change in the characteristic habitats of the biome. Species of plants, animals and insects have to compete with newcomers arriving from sub-tropical eco-regions, and such changes often tip certain species into near-extinction. The arrival in North America and Europe of sub-tropical giant hornets from Asia, which poses an existential threat to native bee populations, is a case in point. Any major loss of indigenous pollinators could pose a serious threat to plant reproduction throughout this biome.

e. Temperate Grassland Biome

-Location

Like temperate forests, these grasslands are found mostly at a latitude of 40–60° north and south of the equator. Grasslands are known by different names in different parts of the World: 'Prairies' in Canada and the United states; 'Pampas' in Argentina and Uruguay; 'veldts' in Southern Africa; 'puszta' in Hungary; and 'steppes' in Russia, China and Mongolia. It is the most widespread of all biomes, but this is due mainly to human deforestation of wooded areas for grazing and agricultural purposes.

The grassland biome is considered by some scientists to be a transitional biome — a halfway stage between the forest and desert biomes. A grassland can turn into either a desert or a forest if climatic conditions (temperature, level of precipitation) change. Basically, grasslands tend to emerge in places where there is not enough rainfall to support a forest, but not so little that a desert biome forms.

The exact origin and evolution of temperate grasslands is unknown, but fossil remains in Chile and the United States suggests that they first formed around 30 million BC, although it wasn't until 21 million BC that the early forests of North America's Great Plains region began to die away due to a drop in global rainfall. (16) Grasses have evolved a more efficient method of photosynthesis that requires less water, and so they could survive in arid areas, while forests could not [28].

-Climate

The temperate grassland biome enjoys hot summers and cold winters, with temperatures varying by as much as 40 °C (72 °F) between summer and winter. Mean January temperatures vary from minus 18 °C (0 °F) in northern areas to 10 °C (50 °F) in the south. Mean July temperatures range from 18 °C (64 °F) to 28 °C (82 °F), sometimes exceeding 100°F (37.8°C). Mean annual temperature in the most northerly areas of the Canadian grassland biome is below 0 °C (32 °F).

Rain usually occurs in the late spring and early summer. The yearly average is 555–950mm (20–35 inches), but much of this falls as snow in the winter. There are two real seasons: a growing season (100–175 days) and a dormant season, dominated by frost, when no plants can grow.

-Soil

Temperate grasslands have some of the richest soils in the world, making them ideal for cultivation and farming. (17) The richness stems from the growth and decomposition of deep, many-branched grass roots that raise the organic content of the soil.

The prairies are the granaries of North America, while the Ukrainian steppes were always seen as the bread basket of Russia. The main grassland crops include: Spring Wheat, Corn, Oats, Barley, Rye, Soybeans, Flax, Canola, Yellow and Green Peas, Edible Beans, Mustard and Sunflowers.

-Plants

Not surprisingly grasses dominate temperate grasslands. The dominant wild grasses include big bluestem, switchgrass, and Indian grass, purple needlegrass, foxtail, ryegrass, and buffalo grass. Many herbivores eat these grasses, but they survive because their growth point is very close to the ground. Also, unlike shrubs and trees, grasses have evolved so that as long as their roots survive, they can grow back after a wildfire very quickly. Wildflowers that grow well in the temperate grassland biome include: asters, blazing stars, clovers, coneflowers, crazy weed, goldenrods, wild indigos and sunflowers.

-Animals

Grasslands offer little or no shelter from predators. The most numerous species are plant-eating ungulates (mammals with hoofs), whose long legs help them to outrun predators. They also travel in herds for protection. Among the animals that inhabit temperate grasslands in North America are bison, elk, antelope, birds, gophers, bobcats, prairie dogs, coyotes, and gray wolves. Birds include: eagles, fly catchers, Canadian geese, as well as wild turkeys and prairie chickens. On the steppes you can also see falcons as well as antelopes, wild horses, and foxes.

-Environmental and Climate Concerns About Temperate Grasslands Biomes

Because temperate grasslands have very rich soil, the majority of grassland in the United States has been converted into fields for crops or grazing land for livestock. Instead of native grasses, grasslands supply corn, wheat, and other grains, as well as grazing for sheep and cattle. Unfortunately, given the pressing need for more food to keep pace with the growing number of people, this native biome is likely to disappear completely.

The big question is, will farmers come up with a sufficiently robust climate change adaptation plan to combat rising temperatures that threaten crop survival. Will they be able to develop heat-resistant varieties of wheat and corn. [29].

f. Savanna Biome

Figure 31. The African savanna.
(Photo: Ray in Manila/CC BY-SA 2.0).

In 1900, more than 100,000 cheetahs roamed the African savanna. Today, less than 12,000 remain. With a top speed of 70 miles per hour, these black-spotted cats hold the record as the fastest land mammal.

Savannas are grasslands with a few trees. Like temperate grasslands, they are considered to be a transitional biome — a halfway point between forest and desert. Popularized by TV wildlife documentaries showing lions chasing wildebeest, elephants stripping trees of foliage, or hippos splashing around in muddy pools, savannas are the location for most African safaris, owing to the presence of so many big game animals.

-Location

The most famous example of the savanna biome is the Serengeti Plains of Tanzania, covering 30,000 sq km (12,000 sq miles) of land. (18) Nearly half of Africa is covered with savannas. But they are also found in South America, India and even Australia. However, these other regions lack the biological diversity of Africa's plants and animals.

Savannas are characterized more by their warm climates than by their grasses and scattered trees. They must have a wet season to allow vegetation to grow, as well as a reasonably long dry season to prevent the growth of trees, as trees cannot usually tolerate drought.

There are two fundamental types of savanna: climatic and derived. Climatic savannas are those created by nature and defined strictly by the climate. Derived savannas are artificially created by humans, usually, as a result of forest being converted to grassland for cattle grazing. Sometimes, animals are responsible. Lightly forested areas in Africa have been converted to savanna because elephants have stripped all the bark and vegetation, bulldozed the trees and tramping on saplings.

-Climate

The Savanna climate is hot with only two seasons: a warm wet season (6–8 months) and a hot dry season (4–6 months). The timing varies from Northern to Southern Hemisphere. In the Serengeti, for example, the dry season runs from June to October, while the wet season runs from November to May, although it is divided into two differing periods. The 'short rains' last from November to December, and the 'long rains' from March to May.

In fact, the length of the dry season determines the category of savanna. In wet savannas, dry seasons usually last 3–5 months; in dry savannas, 5–7 months, and in 'thorn bush savannas' 8 months or longer. During this period no more than 75–100mm (3–4 inches) of rain will fall. Which is why you don't see many trees.

Mean annual temperatures range from 20 to 30°C (68° to 86°F). Annual rainfall is 250–1200mm (10–50 inches) per year, but nearly all of this falls in the wet season. Tropical grasslands get hot and very humid during the wet season. Every day the warm humid air rises and collides with cooler air above, and turns into rain. In the afternoons, the rains can pour for hours, allowing the grass and other vegetation to grow thick and lush, creating a perfect habitat for herbivores and predators to feed [30.

-Plants

Vegetation in the tropical savanna biome is dominated by grasses. Species include: star grass, Rhodes grass, red oats grass, lemon grass, and some shrubs. Most types of grass are coarse and grow only in patches interspersed with areas of bare ground. Only individual trees (baobab tree, acacia tree), or small groves of trees are found, usually near streams and pools. (19)

The challenge for any plant in this environment is to survive long periods of drought. To do this, many plants have developed long tap roots that can reach as far as the deep-water table, as well as thick bark to resist annual wildfires, and trunks that are able to store water. Grasses have found ways of discouraging animals from grazing on them; they may be too sharp or bitter tasting for some animals, but okay for others. Different species prefer to eat different parts of the grass. Many grasses grow from the roots up, so that the growth tissue doesn't get damaged by herbivores.

-Animals

The savanna biome is home to a wide diversity of animals, although not all species found in Africa are found elsewhere. The best-known animals include: African elephants, lions, leopards, cheetahs, wild dogs, hyenas, warthogs and buffaloes. When it comes to herbivores, who provide most of the prey for predators, they include: zebras, giraffes, wildebeest, gazelles, antelopes, and impala, to name but a few. In all there are more than 40 species of hoofed mammals living in the African savanna.

The intense competition for water during the dry season drives birds and many of the large mammals to migrate in search of water. The great Serengeti wildebeest migration, for example, involves millions of Grant's gazelle, Thomson's gazelle, eland, impala and zebras, in a circular migration in search of fresh grazing and better-quality water. The exact timing of the migration depends entirely on the year's particular pattern of rainfall.

To cope with the searing heat of the dry season, some animals dig burrows in the ground, where they can escape the heat of the day, or provide shelter for their young. Others (hippos, crocodiles) wallow in the mud of the dwindling water holes.

Some animals are able to exploit the heat. There are many species of birds of prey overflying the savanna, including eagles, hawks, buzzards and vultures. Because hot air rises, the birds can soar on the air using almost no energy. They can spend all day soaring over large areas of land, using their keen eyesight to spot prey.

Some creatures burrow but fail to escape the attentions of specialist predators. Termite mounds, for instance, are a common sight on the South African veldt and elsewhere. In fact, there are more than 1,000 different kinds of termites living in African savannas — more than anywhere else in the world. These termite colonies support numerous predators, such as the aardvark and aardwolf in Africa, and giant anteater in South America.

Ultimately, the ecosystem of the savanna is based on a balanced system of interdependence. Herbivores are the major food source for most predators, but they also depend upon predators to eliminate aging or diseased animals, to maintain the health of the herds.

To reduce unnecessary competition for scarce food resources, each of the many species of herbivores has its own preference for grass, allowing up to 16 different species of grazers to coexist in the same area at one time. In addition, most of the herds keep moving.

By contrast. in several areas of the African savanna, farmers have begun using it to graze their cattle and goats. They don't move their herds around, so the grasses are soon completely eaten, turning the now grassless plain into a desert. Considerable areas of savanna are lost to the Sahara Desert every year due to overgrazing.

-Environmental and Climate Concerns About Savanna Biomes

Humans are the biggest danger to the tropical grassland biome and its biodiversity of plants and animals. Poaching, expansion of farming and commercial development, do untold damage to animals and birds. The impact of climate change is also being felt, as rising temperatures evaporate water supplies and damage animal habitats. Growing populations are likely to increase the pressure on food and land resources, damaging the savanna biome in the process.

g. Tropical Rainforest Biome

Tropical rainforests are one of Earth's most important and most fragile ecological environments. In recent decades, almost half of the rainforest biome has disappeared due to deforestation and commercial development [31].

-Location

Tropical rainforests cover roughly 6 percent of the Earth's land surface and are generally located around the world, between 30°N and 30°S. They occur in Central and South America; in Western Africa, and the Congo basin; and along the west coast of India, Southeast Asia, New Guinea, and Northern Queensland, Australia. The largest and most famous example is the Amazon Rainforest, most of which is in Brazil. The next largest is the Congo Rainforest in Equatorial West Africa.
The rainforest biome is critically important to Earth's climate because it helps to maintain global weather patterns and rainfall, while acting as a home to the world's largest collection of animal and plant species.

-Climate

The climate of the tropical rainforest biome is hot and wet all year round. The average temperature hovers around 21–30°C (70–85°F), and doesn't vary much even between night and day. The humidity remains between 77 percent and 88 percent all year-round. Mean average rainfall is 2000–10000mm (80–400 inches) annually.

-Plants

Most trees in tropical rainforests have thin, smooth bark, which makes it difficult for other plants, such as epiphytes, to grow on their surface. Trees often have large branching ridges near their base, to help offset their shallow roots. Many plants have adapted leaf shapes that allow water to drain away quickly to minimize surface moisture that might facilitate the growth of bacteria and fungi.

-Trees

Tropical rainforests are commonly divided into four layers. The top layer of the rainforest is called the emergent layer. This is headed by giant trees that are much taller than their shorter companions below.

The next layer down is the canopy. It consists of trees standing 18 to 45 meters (60 to 150 feet) tall. Their branches form a canopy, not unlike a big golf umbrella, that shades the forest floor. Thick, woody vines (such as lianas) also form part of the canopy. They climb the trunks of trees in the canopy in order to reach for sunlight.

The next layer down, the understory, is a dark, cool area which is below and shaded by the canopy, but above the ground. Beneath the understory is the forest floor, the bottom layer of the rainforest. This is where fallen branches, plants and forest litter lie, rapidly decomposing thanks to the millions of bacteria, fungi, insects and other decomposers that work hard to recycle nutrients contained in the rotting vegetation and animal remains.

-Animals

Tropical rainforests provide shelter for half the plant and animal species on Earth. Scientists believe this diversity of animals stems from the fact that rainforests are one of the oldest ecosystems on earth. Some Southeast Asian forests are at least 100 million years old.

Animals able to survive the tropical rainforest have invariably adapted themselves to live in this unique environment. For example, many mammals, birds, reptiles and amphibians have developed the ability to live in trees. Most animals in the tropical rainforest biome, live in the canopy. It's safer, and food is abundant.

Birds play an important role in rainforests because they eat seeds and fruit. Their seed-rich droppings grow into new plants and help rainforests to propagate. Monkeys also eat fruit, spitting out seeds onto the forest floor with similar effect, as they move from tree to tree. In turn, tropical rainforests are important to birds because they provide winter grounds as migratory destination.

The tropical rainforest biome provides oxygen, absorbs more carbon dioxide than it releases, creates its own rainfall, plays a vital role in the water cycle and the carbon cycle, and is home to an astonishing diversity of trees, plants, animals, birds and insects.

Rainforests also provide people with food and a host of spices, including: allspice, bananas, black pepper, cacao, cassava, ginger, nutmeg, sugar cane, vanilla, and many more. A number of large pharmaceutical companies maintain research offices in the Amazon, to bio prospect for new pharmacological and medical materials. A huge proportion of drugs originate from inside the rainforest biome [32].

-Effects of Humans and Climate Change on Tropical Rainforest Biomes

Unfortunately, many unemployed people are moving into the rainforest from crowded cities in order to become small farmers. They use slash-and-burn methods to clear the land either for their own smallholdings or for larger ranchers.

Add to this, an increase in logging operations for fuelwood, charcoal, building materials and other uses, as well as the mining for gold, bauxite, and other minerals, and you can see the stress that is being placed on rainforests around the world.

Most of the African rainforest has already been cleared. (According to the U.N. FAO, during the period 2000–2005, Nigeria lost more than half of its primary forest. During 2014–2018, the rate of deforestation in the Democratic Republic of Congo doubled.) Deforestation in the Amazon Rainforest is also significantly up, while surviving tracts in the Philippines and Sumatra are equally threatened [33].

Climate change is also having an effect. As temperatures rise, there is a risk that rainforests — notably those in the Amazon Basin — will dry out, leading to a savannization of the entire Amazonian biome. This may lead to a significant change in the climate of Central America and the Southern United States [33].

h. Desert Biome

Desert biomes are characterized by extremely low rainfall. In fact, deserts are the driest places on Earth, making them inhospitable to most forms of life. (23) Most experience periods of intense drought during which rain may not fall for several years. Not surprisingly, desert biodiversity of plants and animals is very low.

-Location

Generally, deserts are located between 15° and 30° north and south of the equator (the mid-latitudes), typically in a belt of high pressure (sinking air) and very low rainfall. The best-known deserts include: the Sahara Desert (North Africa), the Arabian Desert (Arabian Peninsula), the Western Deserts of Australia, the Kalahari Desert (Southern Africa), the Mojave Desert (USA) and the Atacama Desert (Chile & Peru).

-Climate

The desert biome climate is extremely hot and dry, typically receiving less than 250mm (10 inches) of rainfall per year. In some deserts, it might rain only once every two or three years. And when it does, the rain often falls in short violent bursts. Occasionally, the rain evaporates before even hitting the ground, while the hard ground often means that the soil is unable to absorb more than

a tiny amount, leaving most to be lost in run-off. It is extremely hot during the day, with temperatures averaging 38ºC (100ºF). Cloudless skies during the early hours of darkness ensure that most of the daytime heat escapes, causing night-time temperatures to plunge as low as minus 4ºC (24ºF). The temperature also varies according to the location of the desert.
By contrast, coastal deserts, like the Atacama Desert on the western coast of South America, are found in moderately cool to warm areas. They usually experience cool winters (average 5ºC/41ºF) followed by long, warm summers (12–24ºC/55–75ºF). Rainfall remains extremely low, however, averaging 80–130mm (3–5 inches) annually. Although it has a relatively mild climate, the Atacama is the Earth's driest desert, with 1mm or of rain about every 5–20 years [33].

-Plants

To cope with the arid conditions, desert plants need to excel at storing and finding water. Some plants, like cacti, have shallow roots that are widely spread allowing any rain to be absorbed immediately. They store water in their stems and use it very slowly, while other plants conserve water by having large root systems to gather water from the deep-water table. Some plant species live only for a few weeks, during periods of rain. 24 Other common plants that inhabit the desert include sagebrush, creosote bush, and ocotillo.
Coastal deserts house a variety of plants, such as black sage, chrysothamnus, rice grass and salt bush. These plants grow complex root systems that come up to the surface to absorb any possible rainfall, and also stretch deep down to absorb any water held in the ground. These plants also develop very thick leaves that can absorb water whenever it becomes available.

-Animals

The desert biome is home to a mixed bag of animals. The most famous animal in the desert is the camel. Camels are extremely well adapted. They have two rows of eyelashes to protect their eyes from the dust; they carry fat in their hump so they can go for days without food and they can close their nostrils to stop them inhaling sand.
Kangaroo rats are another success story. They live in complex burrow systems, sometimes in colonies of several hundred dens. To ensure a cool temperature in their burrows, they plug the entrances with soil during the day and venture out only at night. kangaroo rats are extremely fast and agile, and can often leap up to 2.75m (9 feet) at speeds up to 2.75m (10 ft) per second. Kangaroo rats are mostly seed eaters and often store the seeds of mesquite, creosote bush, purslane and ocotillo in seed caches for future use.
Other desert animals that avoid the sun are the nocturnal fennec fox, who comes out to hunt only after sunset, and the desert tortoise that also spends much of its time underground.

The Armadillo Lizard of the deserts of Southern Africa, relies on camouflage, an ability to freeze, and a thick skin to survive the attentions of predators. It lives in the cracks and crevices of large rocks.

Figure 32. Meerkats are found in the western and southern parts of Africa, in the Kalahari Desert. A highly social animal they usually stick together in groups of 10 to 30 individuals.
(Photo: Charles James Sharp/CC BY-SA 4.0).

Like the kangaroo rat, the meerkats of the Kalahari Desert in Southern Africa live in complex underground tunnel systems that they have either dug or inherited from a previous occupant. While a group of meerkats is hunting for food, one or more will act as lookout on its hind legs to watch for predators.
The Sidewinder Rattlesnake of the Southwestern United States uses venom to kill its prey. During the day it hides in the sand or in animal burrows, before emerging at night to hunt.

-Effects of Humans and Climate Change on Desert Biomes

Deserts have probably the least to fear from climate change as they deal with hot and arid conditions every day. It's actually the semi-arid eco-zones adjacent to it, that are suffering. They are suffering from desertification, caused mostly by deforestation and the degradation of the soil through over intensive grazing, agriculture and loss of vegetation, all of which encourage soil erosion by wind and water.

In China, inappropriate land use in the form of expanding urbanization has left much of the land exposed to wind erosion and dust storms from the surrounding desert, necessitating the construction of a so-called "great green wall" to hold back the advancing desert.
Global warming is only likely to exacerbate these environmental problems by exaggerating extreme weather events and climate oscillations, leading to more severe drought, heatwaves, and flooding. Ironically, far from shrinking the desert biome, climate change is likely only to enlarge it.

i. Freshwater Biome

Figure 33. Fresh water lake in Switzerland.
(Photo: CC0 Public Domain).

The freshwater biome is one of Earth's aquatic ecosystems and an important element in the ecology of the hydrosphere. It encompasses three basic environments: (a) lakes and ponds, (b) streams and rivers, and © wetlands. These habitats are classified as either "lentic" (still water) – which includes ponds, lakes, and wetlands; or "lotic" (flowing water) – which includes streams and rivers; or "groundwaters" which flow in aquifers and rocks. Note: the terms freshwater and fresh water are interchangeable. [34].

VI.2. The forest biome

Figure 34. A Wisconsin forest.
(Photo: CC0 Public Domain).

About 420 million years ago, during the Silurian Period, ancient plants and arthropods began to occupy the land. Over the millions of years that followed, these land colonizers developed and adapted to their new habitat. The first forests were dominated by giant horsetails, club mosses, and ferns that stood up to 40 feet tall.

Life on Earth continued to evolve, and in the late Paleozoic, gymnosperms appeared. By the Triassic Period (245-208 mya), gymnosperms dominated the Earth's forests. In the Cretaceous Period (144-65m mya), the first flowering plants (angiosperms) appeared. They evolved together with insects, birds, and mammals and radiated rapidly, dominating the landscape by the end of the Period. The landscape changed again during the Pleistocene Ice Ages — the surface of the planet that had been dominated by tropical forests for millions of years changed, and temperate forests spread in the Northern Hemisphere.

Today, forests occupy approximately one-third of Earth's land area, account for over two-thirds of the leaf area of land plants, and contain about 70% of carbon present in living things. They have been held in reverence in folklore and worshipped in ancient religions. However, forests are becoming major casualties of civilization as human populations have increased over the past several thousand years, bringing deforestation, pollution, and industrial usage problems to this important biome.

Present-day forest biomes, biological communities that are dominated by trees and other woody vegetation (Spurr and Barnes 1980) [35], can be classified according to numerous characteristics, with seasonality being the most widely used. Distinct forest types also occur within each of these broad groups.

VI.3. Tropical forest

Figure 35. Left: Ranomafana National Park, Madagascar; right: Hawaiian forest. (Photo: CC0 Public Domain).

Tropical forests are characterized by the greatest diversity of species. They occur near the equator, within the area bounded by latitudes 23.5 degrees N and 23.5 degrees S. One of the major characteristics of tropical forests is their distinct seasonality: winter is absent, and only two seasons are present (rainy and dry). The length of daylight is 12 hours and varies little.

- Temperature is on average 20-25° C and varies little throughout the year: the average temperatures of the three warmest and three coldest months do not differ by more than 5 degrees.
- Precipitation is evenly distributed throughout the year, with annual rainfall exceeding 200 cm.
- Soil is nutrient-poor and acidic. Decomposition is rapid and soils are subject to heavy leaching.
- Canopy in tropical forests is multilayered and continuous, allowing little light penetration.
- Flora is highly diverse: one square kilometer may contain as many as 100 different tree species. Trees are 25-35 m tall, with buttressed trunks and shallow roots, mostly evergreen, with large dark green leaves. Plants such as orchids, bromeliads, vines (lianas), ferns, mosses, and palms are present in tropical forests.

- Fauna include numerous birds, bats, small mammals, and insects.

Further subdivisions of this group are determined by seasonal distribution of rainfall:

- *evergreen rainforest*: no dry season.
- *seasonal rainforest*: short dry period in a very wet tropical region (the forest exhibits definite seasonal changes as trees undergo developmental changes simultaneously, but the general character of vegetation remains the same as in evergreen rainforests).
- *semievergreen forest*: longer dry season (the upper tree story consists of deciduous trees, while the lower story is still evergreen).
- *moist/dry deciduous forest (monsoon)*: the length of the dry season increases further as rainfall decreases (all trees are deciduous).

More than one half of tropical forests have already been destroyed.

-Temperate forest

Temperate forests occur in eastern North America, northeastern Asia, and western and central Europe. Well-defined seasons with a distinct winter characterize this forest biome. Moderate climate and a growing season of 140-200 days during 4-6 frost-free months distinguish

VI.4. Temperate forests

Figure 36. From left: Wisconsin woods; a forest along California's north coast; the forested hills of the Adirondacks, New York
(Photo: CC0 Public Domain).

- Temperature varies from -30° C to 30° C.
- Precipitation (75-150 cm) is distributed evenly throughout the year.
- Soil is fertile, enriched with decaying litter.
- Canopy is moderately dense and allows light to penetrate, resulting in well-developed and richly diversified understory vegetation and stratification of animals.

- Flora is characterized by 3-4 tree species per square kilometer. Trees are distinguished by broad leaves that are lost annually and include such species as oak, hickory, beech, hemlock, maple, basswood, cottonwood, elm, willow, and spring-flowering herbs.
- Fauna is represented by squirrels, rabbits, skunks, birds, deer, mountain lion, bobcat, timber wolf, fox, and black bear.

Further subdivisions of this group are determined by seasonal distribution of rainfall:

- *moist conifer and evergreen broad-leaved forests*: wet winters and dry summers (rainfall is concentrated in the winter months and winters are relatively mild).
- *dry conifer forests*: dominate higher elevation zones; low precipitation.
- *mediterranean forests*: precipitation is concentrated in winter, less than 100 cm per year.
- *temperate coniferous*: mild winters, high annual precipitation (greater than 200 cm).
- *temperate broad-leaved rainforests*: mild, frost-free winters, high precipitation (more than 150 cm) evenly distributed throughout the year [35].

Only scattered remnants of original temperate forests remain.

VI.5. Boreal forest

Figure 37. From left: taiga in Jasper National Park, Alberta, Canada; forest west of Stockholm, Sweden. (Photo: CC0 Public Domain).

Boreal forests, or taiga, represent the largest terrestial biome. Occuring between 50 and 60 degrees north latitudes, boreal forests can be found in the broad belt of Eurasia and North America: two-thirds in Siberia with the rest in Scandinavia, Alaska, and Canada. Seasons are divided into short, moist, and moderately warm summers and long, cold, and dry winters. The length of the growing season in boreal forests is 130 days [35].

- Temperatures are very low.
- Precipitation is primarily in the form of snow, 40-100 cm annually.

- Soil is thin, nutrient-poor, and acidic.
- Canopy permits low light penetration, and as a result, understory is limited.
- Flora consist mostly of cold-tolerant evergreen conifers with needle-like leaves, such as pine, fir, and spruce.
- Fauna include woodpeckers, hawks, moose, bear, weasel, lynx, fox, wolf, deer, hares, chipmunks, shrews, and bats.

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