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Second year Common core SNV

Course handout:

General Ecology

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Course for L2-SNV students:

Marine and continental hydrobiology, Ecology and Environment, Agricultural Sciences, Biological Sciences, Food Sciences.

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General Ecology

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Abstract

The course covers the fundamental concepts of sustainable General ecology.
The aim of this course is to make students understand the concept of ecosystem, abiotic and biotic factors and the interactions between these factors, the components of the ecosystem and its functioning. The aim is to make them aware that it is possible to act to preserve the environment, through their education, as well as at their own level, on their consumption, their daily activities and their society. During their university studies, whatever their speciality and their ambitions for their future career, students will have the opportunity to learn about and experience ecology.
Ecology is a global science. Explaining ecology to younger generations stimulates their awareness and refines their individual and collective responsibility.

Preface

Ecology therefore finds its essential, fundamental function here: ecology's sole aim is to save man by saving his ecosystem. In this sense, ecology provides access to an integrative understanding of our environment, to a more solid awareness of our place in the world.

The subject is one of the introductory teaching units in the second semester of the second-year Bachelor's degree in Marine and Continental Hydrobiology. However, it may also be aimed at second-year undergraduate students in : Ecology and Environment, Agricultural Sciences, Biological Sciences and Food Sciences. This course is an educational document for the benefit of students, who will find the necessary information relating to the concept of general ecology. This will enable them to give added value to our environment because of their better understanding of the basics of ecology.

The course content ranges from the definition of concepts in the field of environment to some of the details on which this concept is based.

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Introduction

Ecology is the scientific study of interactions between living organisms and their environment, a field that aims to decipher the complex web of life and how species coexist, adapt, and influence each other within various ecosystems. The comprehensive understanding of these interactions is essential for grasping the organization, functioning, and dynamics of natural systems.

The handout vividly illustrates key ecological concepts through structured chapters that address different aspects of ecosystems. For example, **Chapter III: Ecosystem Structure** introduces the organization of biological communities and their physical settings, emphasizing the importance of species relationships and habitat characteristics. Meanwhile, **Chapter IV: Ecosystem Functioning** details how energy circulates within ecosystems, exemplified by food webs, such as the pond ecosystem with algae, fish, and micro-fauna (p. 38).

A core concept in ecology discussed in the handout is the ecological niche. It explains how species occupy specific roles within ecological communities, with distinctions made between allopatric and sympatric species based on their geographical distribution and interactions. The handout further illustrates the niche with diagrams (p. 34) and discusses its significance in understanding ecosystem structure and function.

The handout also addresses ecological relationships such as cooperation and symbiosis, exemplified by mutualistic interactions like pollination (e.g., bees and flowers) and obligatory symbioses like clownfish and sea anemones, highlighting the diversity of species interactions and their evolutionary importance.

Furthermore, the concepts of environmental factors, their tolerance ranges, and the ecological optimum are fundamental for understanding how species respond to physicochemical variations, affecting population regulation and community stability.These responses—morphological, physiological, or behavioral—underscore the adaptability of organisms within their niches, aligning with the broader themes presented in the handout.

By integrating these foundational concepts, the handout provides a detailed map linking theoretical ecology to real-world examples and mechanisms, enabling a comprehensive understanding of how ecosystems are organized, how they function, and how species coexist and adapt within them. This holistic approach forms the basis for applying ecological.

Chapter I: Ecosystem

1. Definition of the ecosystem and its components (concepts of biocenosis and ecological factor):

1.1. Definition of ecosystem :

Tansley (1935) introduced the term 'Ecosystem' to designate the basic unit of nature. A unit in which plants, animals and habitat interact within the biotope. In other words :

Ecosystem = Biotope + Biocenosis

In 2004, the authors of the report commissioned by the UN and entitled "Millennium Ecosystem Assessment" clearly introduced "necromass" by defining an ecosystem as a "dynamic complex of plants, animals, micro-organisms and surrounding dead nature interacting as a functional unit".

Thus, the definition of an Ecosystem (or ecological system) has two inseparable aspects. The first aspect presents the Ecosystem as being the whole of the biocenosis (all the living beings) and its biotope. The second aspect incorporates the many interactions that exist between the biotope and the biocenosis on the one hand, and between the organisms within the biocenosis on the other hand (Fig.1, 2 and 3).

Wang (2004) highlights five aspects that summarise the main characteristics of an ecosystem:

- An ecosystem is part of a space whose boundaries cannot be explicitly defined. Ecosystems are distinguished from one another by their biophysical attributes and their location.
- An ecosystem is made up of the living organisms within it and the abiotic environment, including pools of organic and inorganic matter.
- Organisms interact with each other and with their environment through flows of energy and organic and inorganic matter present in the pool. Species behaviour and environmental forces mediate these flows and control how they function.
- An ecosystem is a dynamic whole. Its structure and functioning evolve over time.
- An ecosystem has emergent properties. These properties are characteristics specific to the type of ecosystem and do not vary within their area of existence.

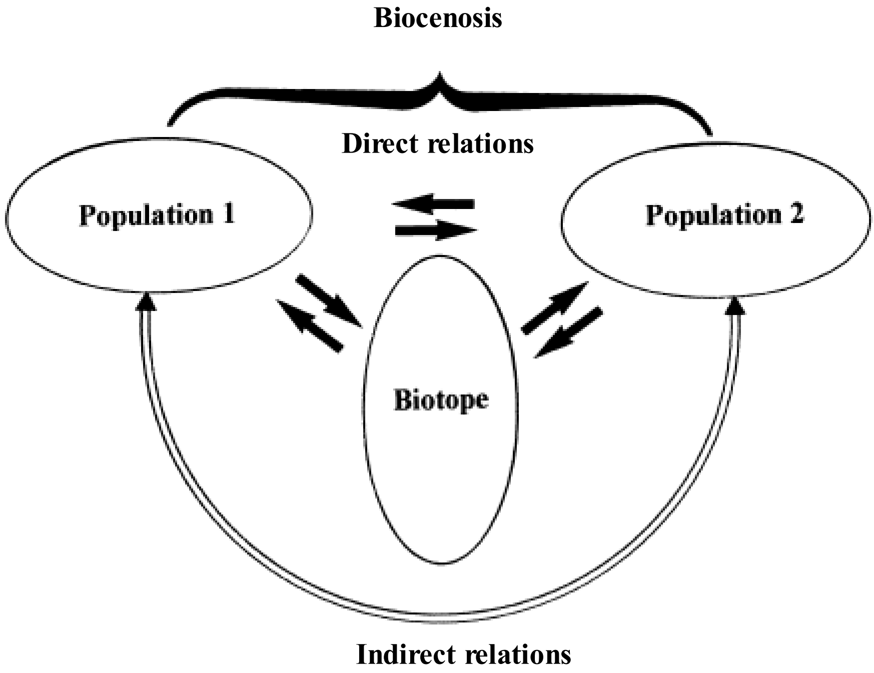


Fig.1. Diagram of how an ecosystem works (According to Frontier and Pichod-Viale *in* Faurie et al., 2012).

1.1.1. The biotope :

The biotope is the physical environment characterised by specific physical and chemical factors (temperature, climate, humidity) responsible for the distribution of a terrain suitable for life for both animals and plants.

In English, the term used as a synonym for biotope is 'habitat'.

1.1.2. Biocenosis:

The biocenosis is the set of living beings (zoocenosis, phytocenosis, microbiocenosis, mycocenosis, etc.) that interact interdependently.

Fig.2. Terrestrial ecosystem

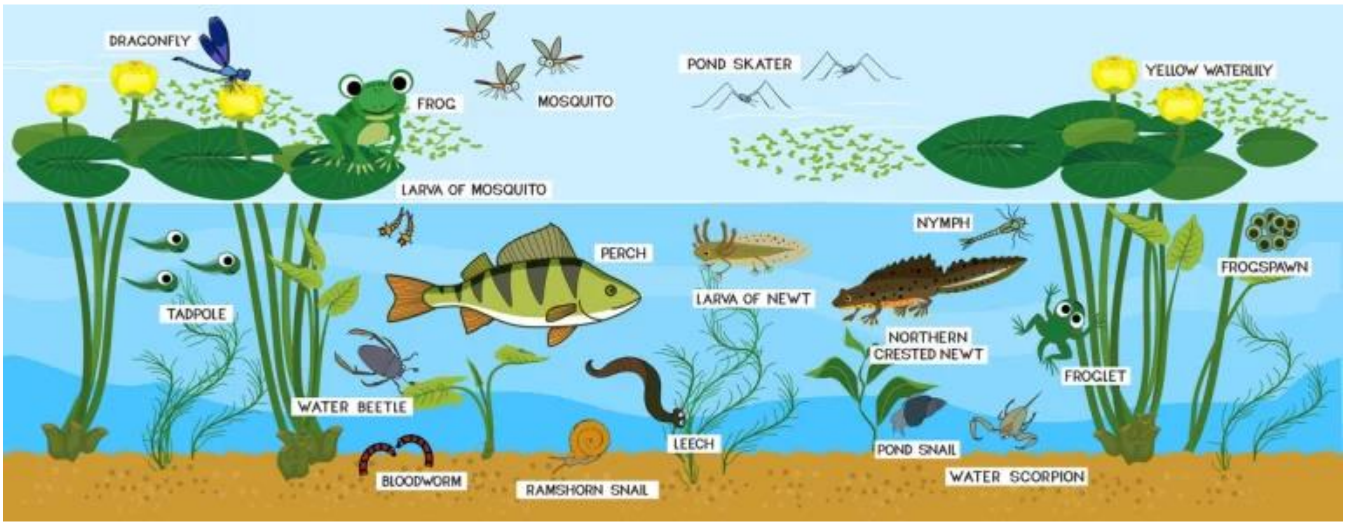


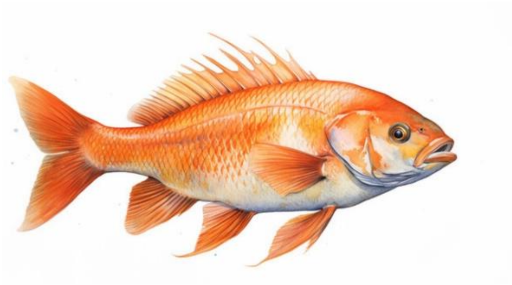
Fig.3. Aquatic ecosystem

1.2 Areas of intervention:

Ecological studies conventionally focus on three levels; the individual, the population and the community: The individual, the population and the community.

1.2.1. Individual:

It is a specimen of a species (Fig.4).



a lion **a fish** **a bee**

Fig.4. Example of some individuals

1.2.2. Population:

A group of individuals of the same species living in the same area at the same time, and able to reproduce among themselves (Fig.5).

The number of individuals is generally defined by the population size (the total number of individuals in the population) or the population density (the number of individuals per unit area) (Singh-Cundy and Shin, 2017). Sometimes the boundaries of a population are clear-cut, such as the shore of an isolated mountain lake for a trout, and sometimes they are more blurred, for example when a roe deer moves easily through two forests separated by a cornfield (Raven et al., 2020).

An elephant population

A population of forage fish

Fig.5. Example of some populations

1.2.3. Biocenosis or community :

The word ‘biocenosis’ was coined by a German biologist, Karl August Möebus, who used the word in 1877 in publications on oysters. He defined a biocenosis as ‘a grouping of living beings whose composition, number of species and number of individuals reflect certain average environmental conditions: these beings are linked by reciprocal dependence’.

In other words, the biocenosis is the set of populations in the same environment (or biotope) that live in the same environmental conditions and in close proximity to each other. We speak of phytocenosis for groups of plant species and zoocenosis for groups of animal species (Fig.6).

Fig. 6. Example of some biocenoses

The three levels mentioned above are the subject of a division of ecology, which are :

- **Autoecology:** the study of the relationship between a type of organism and its environment.
- **Population ecology or population dynamics:** Population ecology is a branch of ecology that studies the population dynamics of a given species in time and space. It is concerned with the size, density, distribution, growth and intra- and interspecific interactions of a population.
- **Synecology:** Synecology is a branch of ecology that studies the relationships between communities of living organisms (called biocenoses) and their environment in a given ecosystem.

Chapter II: Environmental factors

We call an environmental or ecological factor any element of the environment that can act directly or indirectly on living organisms during at least one phase of their development cycle (Dajoz, 1972). When these factors are detrimental to biological cycles, they are known as **limiting factors**.

1. Abiotic factors :

Abiotic factors are related to the physico-chemical conditions of the environment.

1.1. Climatic Factors:

Climate can be defined as the set of atmospheric conditions prevailing in a given region over a long period. These conditions represent the climatic factors.

1.1.1. Light:

Light plays a crucial role in many fundamental biological processes. For example, in aquatic environments, aquatic plants perform photosynthesis thanks to this light.

1.1.2. Temperature:

Temperature plays an important role for living beings. All metabolic processes depend on this factor. For example, photosynthesis, respiration, and digestion follow Van't Hoff's law, which states that the speed of a reaction depends on temperature.

Temperature is measured using a thermometer. There are different types of thermometers, each with its own usage method and measurement environment (Fig.7).

The units of temperature measurement are degrees Celsius (°C), degrees Fahrenheit (°F), and Kelvin (K).

Based on Organisms' Temperature Tolerance, There Are:

- Stenotherms: They tolerate a limited range of ambient temperatures.
- Eurytherms: They are characterized by a high ecological tolerance to temperature variations.
- Microtherms (Oligotherms): They adapt to low temperatures.
- Megatherms (Polytherms): They adapt to high temperatures.

 **Thermometer for measuring air temperature**	 **Water thermometer**
 **Environmental thermometer**	 **Soil thermometer**

Fig.7. Some temperature measuring instruments

1.1.3. Humidity and Rainfall:

Humidity is the amount of water vapor in the air. Relative humidity is the ratio between the amount of water present in a mass of air and the maximum amount of water that this air mass can hold. It is highly proportional to temperature and very sensitive to temperature variations.

Relative air humidity can be measured using a hair hygrometer or a psychrometer. For soil humidity, instruments such as a moisture meter or a humidity tester can be used (Fig.8).

 Un hygromètre à cheveu	 Un psychomètre
 Un humidimètre	 Un testeur d'humidité

Fig.8. Some instruments for measuring humidity

Precipitation is considered one of the main components of Earth's water cycle. It exists in several forms: liquid precipitation (drizzle, rain) and solid precipitation (sleet, hail, snow).

The amount of precipitation reaching the ground, known as the water depth, is measured using different types of rain gauges (Fig.9). This measurement is expressed in millimeters.

 Cône pluviométrique pour mesurer les précipitations	 Pluviomètre
 Pluviomètre électronique	 Pluviomètre

Fig.9. Some instruments for measuring rainfall

According to Their Water Needs and Distribution in Environments, There Are:

- Hygrophilous species: Living in humid environments.
- Mesophilous species: Having moderate water needs and tolerating alternating dry and wet seasons.
- Xerophilous species: Living in dry environments where water scarcity is significant.

1.2. Edaphic Factors:

Edaphic or pedological factors include the physical and chemical characteristics of the soil. Soil forms the superficial layer of the Earth's crust.

1.2.3. Physical Properties of Soil:

- Soil Texture (Tab.1 and Tab.2):

Texture is defined by the percentage of different mineral elements. These elements vary in size: clay, silt, sand, gravel, and pebbles. It corresponds to the granulometric composition of the soil (Fig.10 and Fig.11).

Tab.1: Clay, silt, and sand, which make up fine soil, include the following fractions:

Elements of fine earth	Dimension (µm)
Clay	< 2
Limon fin	2 - 20
Fine silt	20 - 50
Fine sand	50 - 200
Coarse sand	200 - 2000

Tab.2: The coarse elements include the following fractions:

Coarse elements	Dimension (cm)
Gravel	0,2 - 2 cm
Pebbles	2 - 7,5 cm
Stones	7,5 - 20 cm
Blocks	More than 20 cm

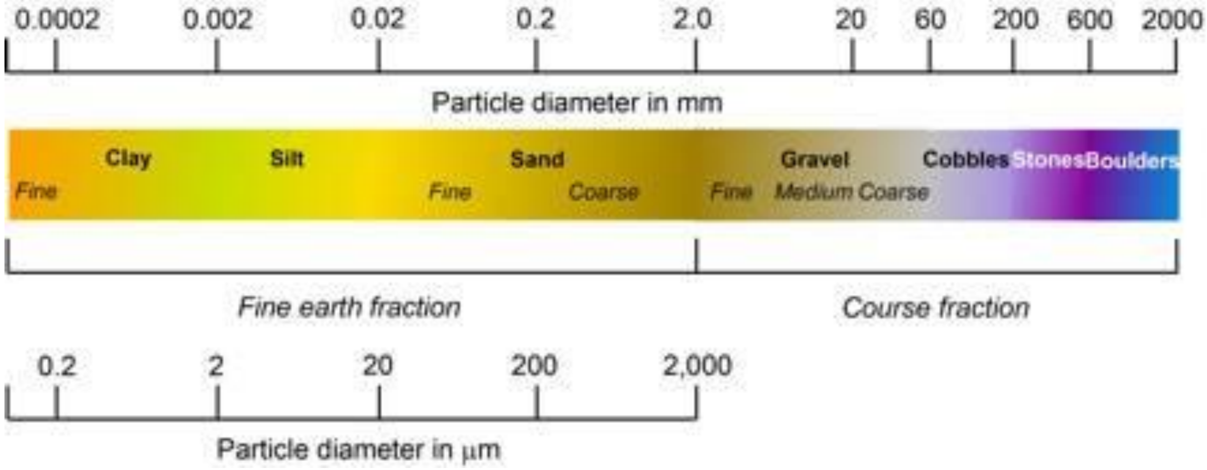


Fig.10. Grain size scale of soil texture

(http://www.terragis.bees.unsw.edu.au/terraGIS_soil/sp_particle_size_fractions.html)

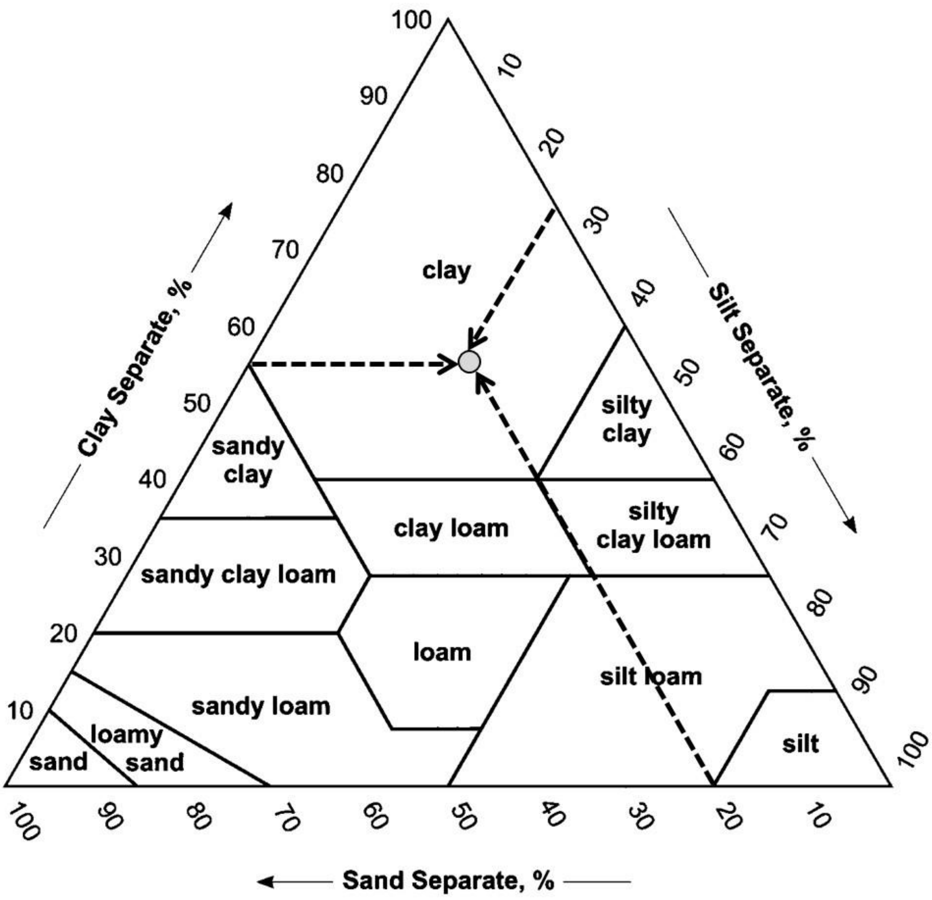


Fig.11. Soil texture triangle example. Figure adapted from King et al. (2003).

- Soil Structure:

Soil structure refers to the arrangement of different soil particles to form aggregates. In other words, an aggregate is the result of the natural organization of solid soil components (Fig.12).

The structure of soil is formed from different components, which can be divided into three groups:

- Materials: Clay, sand, silt, humus.
- Cements: Mucilage, polysaccharides, calcium, iron, aluminum.
- Builders: Biological activity in the soil, roots, fungal hyphae, micro- and macro-organisms.

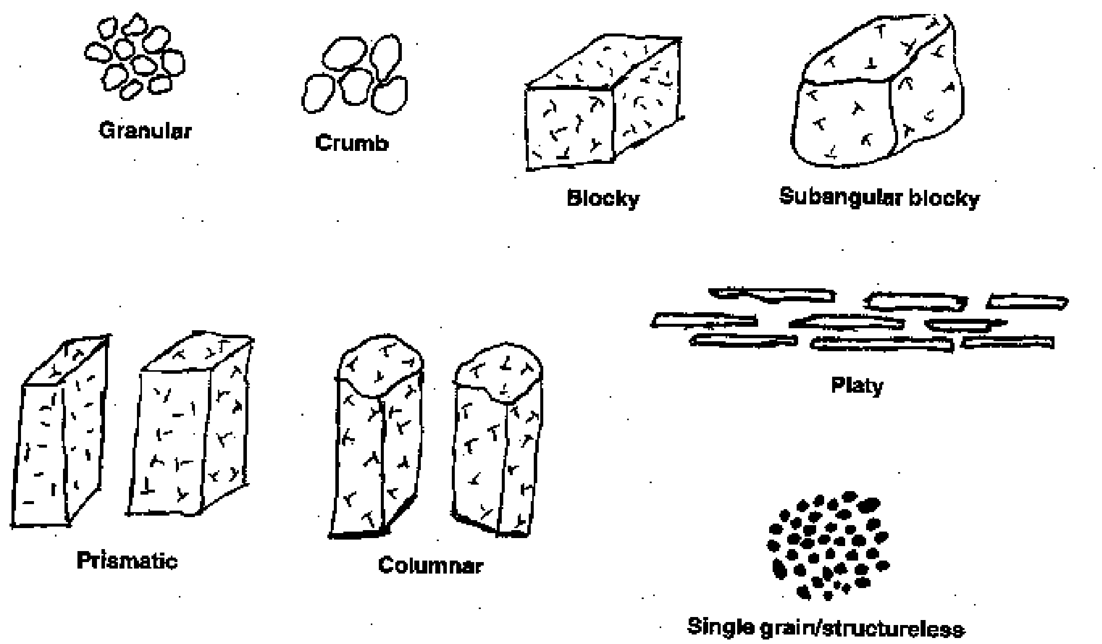


Fig.12. Soil structural types. (James M. Peterson, 1999)

- Porosity:

Porosity is the volume of empty space in the soil occupied by air or water. There are macropores where air circulates and micropores where water circulates.

1.2.2. Chemical Properties of the Soil:

The soil is a chemical complex in the system due to its ability to retain various substances. These properties are essential for understanding soil fertility and its ability to support plant growth. For example, some plants can tolerate salty soils (called halophytes), while others can thrive in high limestone content (called calcicoles), and some plants can only tolerate trace amounts of calcium (called calcifuges).

- pH:

The pH of the soil is a measure of its acidity and alkalinity on a scale from 0 to 14. A pH of 7 is considered neutral, a pH below 7 indicates acidic soil, and a pH above 7 indicates alkaline soil.

pH plays a key role in regulating the availability of nutrients and other soil processes. The pH of the soil can be measured by (Fig.13):

➢ Chemical Test Kit: This type of kit measures pH using a chemical indicator that changes color according to the soil's acidity or alkalinity.

➢ pH Paper: This is a special paper that changes color depending on the pH when immersed in water containing soil particles.

➢ pH Meter: This device typically comes with a probe.

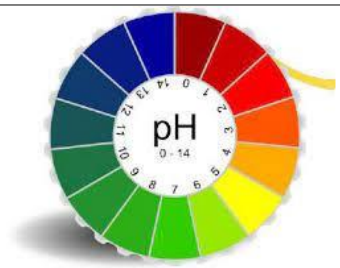
 Kit de test chimique	 Papier pH	 pH mètre

Fig.13. Some pH measuring instruments

- Calcium: Calcium is found in the following forms:
  - ➢ Inactive Limestone: This is calcium carbonate ($CaCO_3$).
  - ➢ Active Limestone: This is the fraction of calcium carbonate ($CaCO_3$).
  - ➢ Soluble Calcium.
  - ➢ Exchangeable Calcium.

The calcium content in these various forms defines the calcium status of the soil.

- Magnesium: Magnesium is found in the following forms:
  - Unchanged Reserve.
  - Mobilizable Reserve.
  - Exchangeable Magnesium.
  - Magnesium present in the soil solution as Mg^{2+} ions.
- Potassium:
  - Potassium is found in the following forms:
  - Potassium firmly bound in primary minerals.
  - Potassium associated with clay.
  - Potassium adsorbed onto the clay-humic complex.
  - Potassium present in the soil solution as K^{+} ions.
- Sodium:
  - Sodium is found in the following forms:
  - Sodium included in the substrate.
  - Sodium adsorbed onto the clay-humic complex.
  - Free sodium in the soil solution as Na^{+} ions.

2. Biotic factors :

Biotic factors are all the actions that living organisms exert directly on each other. These interactions, known as coactions, are of two types:

Homotypic (or intraspecific): between individuals of the same species.

Heterotypic (or interspecific): between individuals of different species.

2.1. Homotypic reactions :

2.1.1. The group effect :

The group effect is observed in animals of the same species when they are grouped in twos or more. It corresponds to any phenomenon within a population which is directly linked to the number of individuals in it.

The impressive grouping of producers directly favours the meeting of the sexes as well as the acceleration of populations by protecting the birth and growth of the young.

2.1.2. The mass effect :

According to Grassé (1952): ‘the group acts essentially through the mass of animals brought together, and this in extremely varied ways: production of a protective substance...;

exhaustion of a toxic substance, and above all modification of the environment by the group itself'.

In environmental terms, mass effect refers to an effect that occurs when there is overpopulation in a given environment, with harmful consequences such as increased mortality. In some organisms, overpopulation leads to phenomena known as self-elimination.

2.1.3. Intraspecific competition :

Intraspecific competition occurs between individuals of the same species. It is caused by mortality factors that depend on population density: malnutrition and its consequences, juvenile mortality, cannibalism.

Example:

The case of two Asian wild dogs (*Cuon alpinus*). Intraspecific competition between two individuals of the same species for prey (Fig.14).

Fig.14. Two wild dogs of Asia (*Cuon alpinus*)

2.2. Heterotypic reactions :

2.2.1. Interspecific competition:

Interspecific competition occurs between individuals of different species in their active search for the same environmental resource (food, shelter, egg-laying site, etc....), where each species acts unfavourably on the other.

According to the principle of competitive exclusion, two species competing for the same limited resource cannot coexist, as one of them is inevitably eliminated.

Example:

Interspecific competition for food between lions and hyenas (Fig.15).

Fig.15. Lions and hyenas

2.2.2. Predators and pests :

Predation occurs when a free-living organism (the predator) consumes another organism (the prey). The predator kills its prey in order to eat it. The consequences are positive for the predator and negative for the prey.

Predators can be :

- Polyphagous, in which the predator feeds on a large number of species.
- Oligophagous, where the predator feeds on a few species.
- Monophagous, where the predator feeds on a single species.

Predators play an essential role in ecosystems and in the balance of populations. Their presence influences the structure, dynamics and health of biological communities.

A pest or predator is an animal that causes damage to a plant or foodstuff, usually in order to feed and sometimes to mark its territory. Examples include insects, mites and nematodes.

Example:

A lion (predator) attacking a zebra (prey) (Fig.16).

Fig. 16. A lion and a zebra.

2.2.3. Cooperation and symbiosis :

Cooperation or mutualism is a positive interaction between two species in which each species enjoys the benefits that only the other species can provide. It is an association of reciprocal benefits that is not essential.

Example:

The bee collects pollen from the flower, which it uses for food. For the plant, it provides the opportunity to reproduce. The benefit is mutual (Fig.17).

Fig.17. A bee and a flower

Symbiosis is an obligatory and indispensable association between two species, each of which derives benefits from this relationship without necessarily depending on the other. Separation of the partners involves damage that can lead to death.

Example:

In the sea, the clownfish lives in an obligatory symbiosis with a sea anemone. The anemone provides the clownfish with protection and shelter, while the clownfish provides the anemone's nutrients in the form of waste, while scaring off potential predatory fish (Fig.18).

Fig.18. The clown fish and a sea anemone

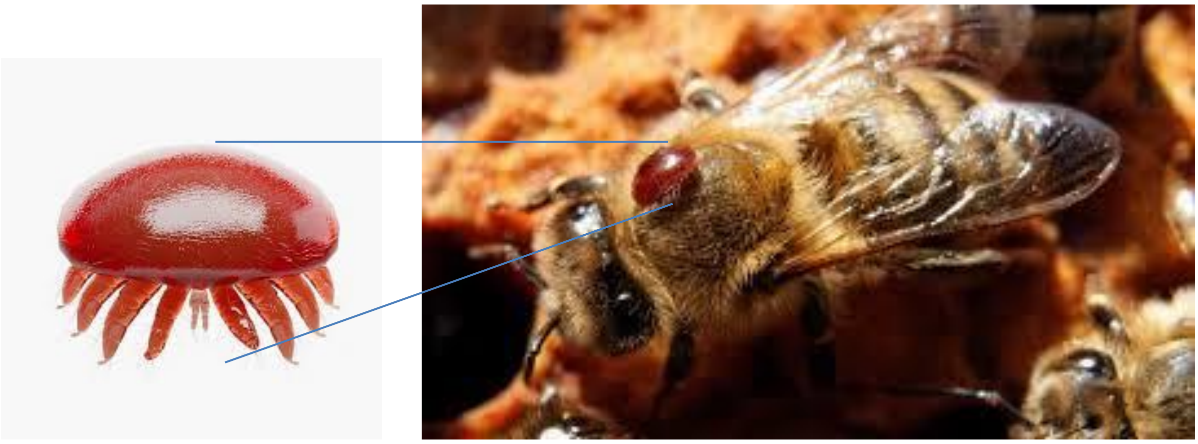
2.2.4. Parasitism :

Parasitism is a temporary or permanent association of two living beings from which only one, the parasite, obtains the food it needs to survive.

A parasite is an animal or plant organism that draws its resources from one or more hosts, usually without killing them.

Example:

Varroa destructor is a species of mite that parasitises adult bees (Fig.19).



Varroa destructor Adult bee

Fig. 19. Adult bee and *Varroa destructor*

Depending on the location, a distinction is made between :

- ectoparasites or external parasites (e.g. fleas, ticks, lice, etc.) living on the surface of the skin.
- endoparasites or internal parasites (e.g. tapeworms, roundworms, hydatid cysts, digestive and respiratory strongyles, liver flukes, etc.) living in the various tissues and deep cavities of the body.

2.2.5. Commensalism:

Commensalism is a relationship between two species, one of which benefits while the other suffers no damage or benefits. This is the case for many organisms that live in the nests, burrows and shelters of other organisms.

When one organism (the smaller one) is carried by another (the larger one), we speak of phoresis, which is a form of commensalism.

Example:

Birds that nest in trees get a place to build their nests and protection from the trees. The trees derive nothing from this relationship, neither benefit nor harm (Fig.20).

Fig. 20. A bird nests in a tree

2.2.6. Amensalism:

Amensalism is an interaction in which one species inhibits the development of another species, through its behaviour or metabolism, without benefiting from it.

Example:

Redwood trees block sunlight with their branches, preventing plants from growing nearby (Fig.21).

Fig. 21. The sequoias

2.2.7. Neutralism:

Neutralism is when two species, cohabiting on the same territory, are independent, without having any influence on each other.

Example:

A rainbow trout and a dandelion in a mountain valley (Fig.22).

A rainbow trout a dandelion

Fig22. A rainbow trout and a dandelion.

Tab.3. Types of species interactions

Biotic interaction		
Type	**Species 1**	**Species 2**
Mutualism	(+)	(+)
Commensalism	(+)	(0)
Amensalism	(-)	(0)
Competition	(-)	(-)
Predation	(+)	(-)
Parasitism	(+)	(-)
Neutralism	(0)	(0)
(+) Benefited (-) Harmed		
(0) Neither Benefited nor Harmed		

2.3 Interaction between environments and living organisms :

2.3.1. The role of ecological factors in population regulation :

There are responses to the changes that occur during life on different scales, daily, seasonally or throughout life. These responses occur in the face of physico-chemical variations in the environment. They may be morphological, physiological or behavioural responses.

2.3.2. Notion of ecological optimum :

According to Shelford's law of tolerance, for any ecological factor there is a tolerance interval within which any ecological process dependent on that factor can proceed normally. This law can be represented by a bell-shaped curve. At the level of this curve there is (Fig23):

- A lower limit: above which organisms die from deficiency.
- An upper limit: above which organisms die of toxicity.
- Within the tolerance interval: there is an optimum value, known as the 'preferendum' or 'ecological optimum', at which the metabolism of the species or community in question proceeds at maximum speed.

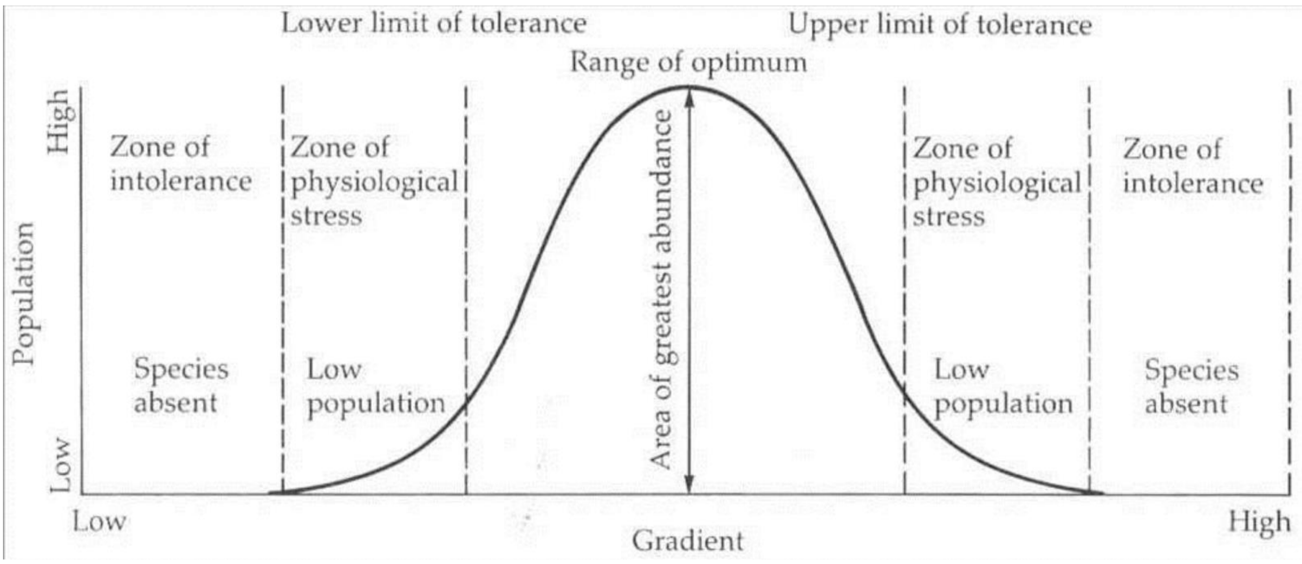


Fig.23. Tolerance range.

2.3.3. Ecological valence :

The ecological value of a species is its ability to develop in different environments characterised by greater or lesser variations in ecological factors. A distinction is made between :

- A species with high ecological valence: characterised by a high tolerance to a given environmental factor. It is known as a euryceae.
- A species with low ecological value: characterised by low tolerance to a given environmental factor. It is known as a steno species.

2.3.4. Ecological niche :

The concept of the ecological niche is fundamental to ecology but also one of the most challenging to comprehend because:

- It takes into account several parametric elements characteristic of the environment (physical, chemical and biological), which evolve over time.

- It remains a purely theoretical concept in which we try to describe the spatio-temporal position of individuals in this ecosystem.

The term appeared at the beginning of the 20th century (1904) and has remained so ever since, but the concept has undergone numerous reformulations. The term was initially vaguely defined and used to describe the ecological position, habitat and requirements of species (Packard 1894; Grinnell 1917; Allen 1882, see Gibson-Reinemer 2015).

First composed definitions of the ecological niche were presented by Elton (1927) and Grinnell (1928). Elton (1927) defined the ecological niche in terms of the species' function within a community and its relations to other species.

Odum (1971) sees the niche as the species' function within the ecosystem, its “profession”.

Based on all these considerations, we can define the ecological niche in a simpler framework, as being both the address (habitat) and the occupation (specialisation) of a species. It is the place and role that a species occupies in the functioning of the ecosystem (Fig.24). This definition therefore takes into account

- The function of the species: what it eats, how, when, where, ...

- Its environment: its relationships with other species, its habitat, etc.

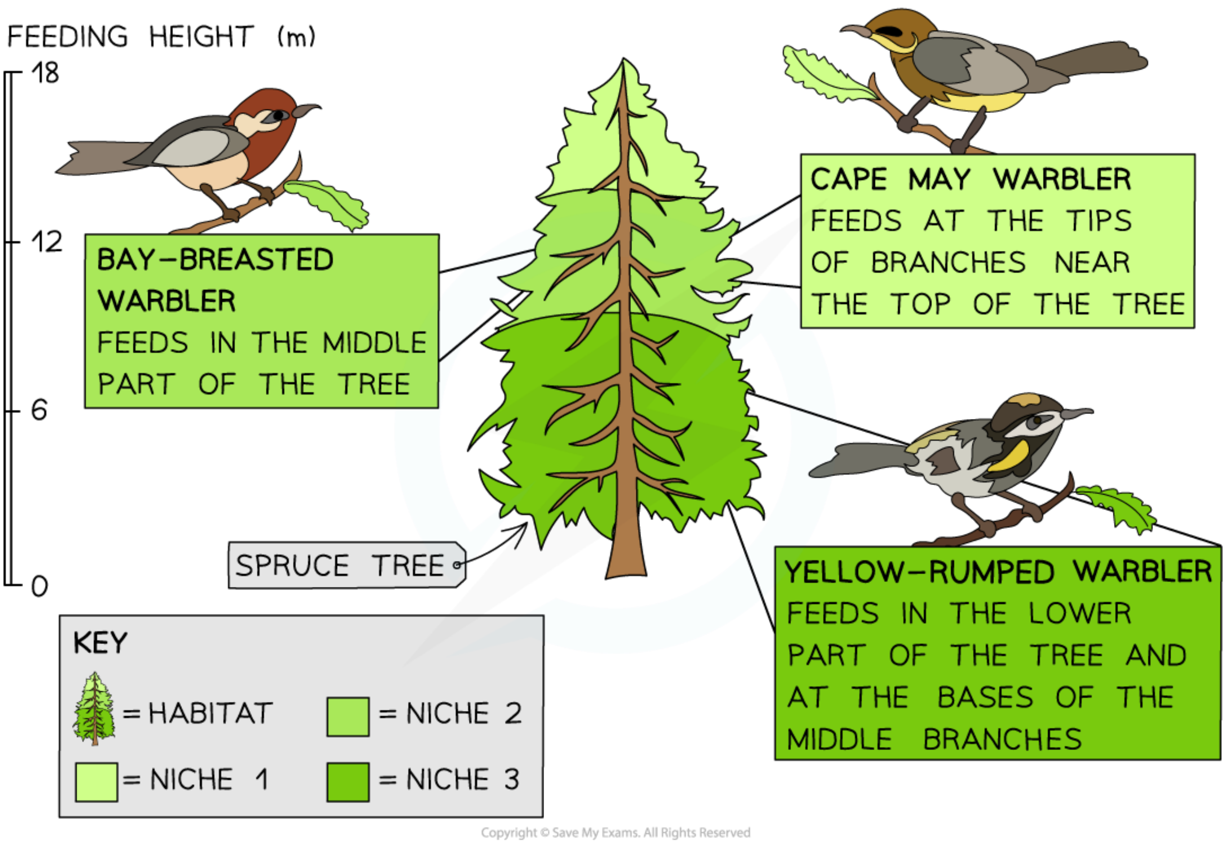


Fig. 24. Example of ecological niche (https://www.savemyexams.com/dp/biology/ib/23/sl/revision-notes/form-and-function/ecological-niches/ecological-niches/)

Understanding the ecological niche helps us grasp the structure and organization of ecosystems and addresses questions such as::

- Where and at whose expense does a given species feed?
- By whom is it eaten?
- How and where does it rest?
- How does it reproduce?

According to the concept of ecological niche, a distinction is made between :

- Allopatric species: species that are geographically distant and may have similar functions, since they are not present in the same environment. Their ecological niches may be separate, contiguous or overlapping.

- Sympatric species: species that are both present in the same environment and will want to occupy the same ecological niche: there will be competition. Their ecological niches may partially overlap or one may be completely included in the other.

Chapter III: Ecosystem structure

1. The concept of a food chain (trophic chain):

A food chain or trophic chain is a sequence of living beings in which some eat those that precede them in the chain, before being eaten by those that follow them. Each level or link in a trophic chain constitutes a trophic level.

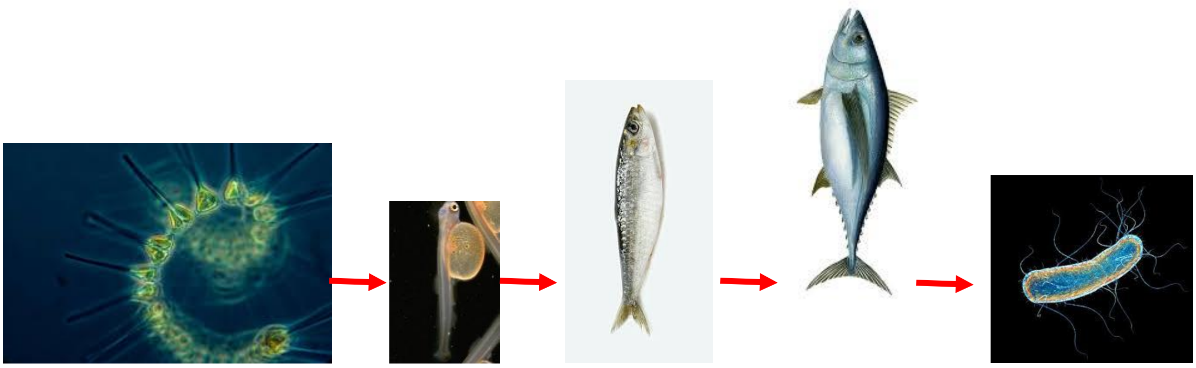
The food chain helps us to understand the relationships between living things in a given environment.

Example: (the scales of the images in the three examples below are not respected, to be able to see all the components of the food chain)

In the forest:

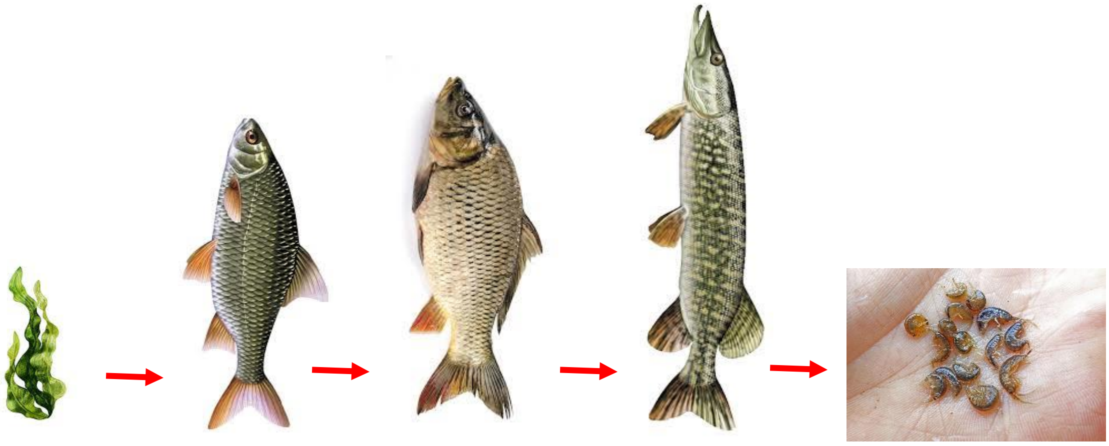
herbaceous plants beetles blackbirds birds of prey decomposers.

In the sea:



Phytoplankton fry sardines tuna bacteria.

In the pond:



Algae roach carp pike micro-fauna.

A food web is the set of food chains that exist within an ecosystem, which link organisms in an ecosystem and through which energy circulates. The food web represents the complex relationships between all these organisms (Fig.25).

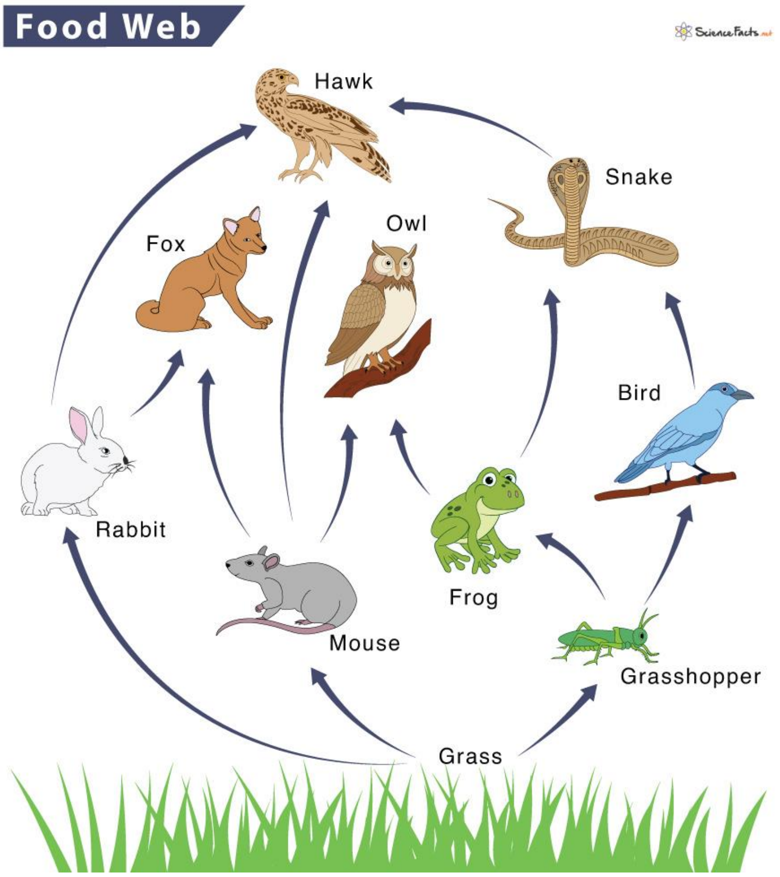


Fig.25. Food web

(https://www.sciencefacts.net/food-web.html)

1.1. Producers :

Most producers are autotrophic plants that feed themselves. Algae, phytoplankton and vascular plants produce their own organic matter using a fraction of the sun's energy, carbon dioxide, water and mineral salts. They are autotrophic.

On land, primary production takes place through photosynthesis by plants, such as forest trees.

In marine environments, plants are generally represented by phytoplankton such as diatoms, dinoflagellates and cyanobacteria. These organisms form the basis of trophic food chains.

1.2 Consumers:

Consumers are obliged to use complex organic products as a source of energy. They are heterotrophs.

We divide this group into two sub-groups, primary consumers and carnivores (secondary and tertiary consumers).

1.2.1. Primary consumers :

Primary consumers feed on plants in various forms.

In the terrestrial environment, they are represented by :

- **Herbivores**: animals that eat grass, leaves and other plants (e.g. horses, giraffes, cows).
- **Frugivores**: animals that eat fruit (bats, shrews, glirids).
- **Granivores**: animals that eat seeds and dried fruit (e.g. red squirrels, hens, pigeons),
- **Nectarivores**: animals that feed on nectar, a sugar-rich substance produced by flowering plants (e.g. bees, hummingbirds).

In the marine environment they are mainly represented by zooplankton.

1.2.2. Carnivores :

Carnivores or secondary consumers feed on the primary consumers that represent their prey by capturing them most of the time. The prey-predator interaction describes zoophagy. There are two types of carnivores:

a. Herbivore consumers or secondary consumers (C2) consume primary consumers.

Example: The lynx, one of whose prey is the hare (Fig26).

Fig.26. The lynx and the hare

b. Consumers of carnivores or tertiary consumers (C3) consume secondary consumers. Example: The wolf, one of whose prey is the lynx (Fig27).

Fig. 27. The wolf and the lynx.

1.2.3. Parasites :

Parasites are not free beings. They lengthen food chains and are linked to their host for at least one stage of their life. Their action adds to that of other consumers and makes food webs more complex.

1.3. Detritivores and decomposers :

Detritus feeders and decomposers are involved in the mineralisation of various elements. They play an important role in the recycling of matter and therefore in the functioning of ecosystems. Without them, dead organisms and waste would accumulate indefinitely.

1.3.1. Detritus feeders :

Detritus feeders consume detritus. This is organic matter from animal carcasses, decomposing plants and excrement. These organisms look for organic matter on the bottom. This is the first stage in the breakdown of dead organic matter.

There are several categories of detritivores depending on where or what they consume:

- Necrophagous: Feeding only on animal corpses. E.g.: Necrophores (beetle insects).
- Coprophagous: feeding on excrement. Example: Dung beetle.
- Saprophages: feed on decomposing plant material. Example: Sowbugs (terrestrial crustaceans).
- Geophagous: soil animals that play a key role in humification. E.g.: earthworms

1.3.2. Decomposers :

Decomposers are known as saprophages, which are responsible for mineralisation proper and carry out the second stage in the transformation of dead organic matter, drawing their energy from the products of this decomposition.

These organisms are mainly fungi and bacteria.

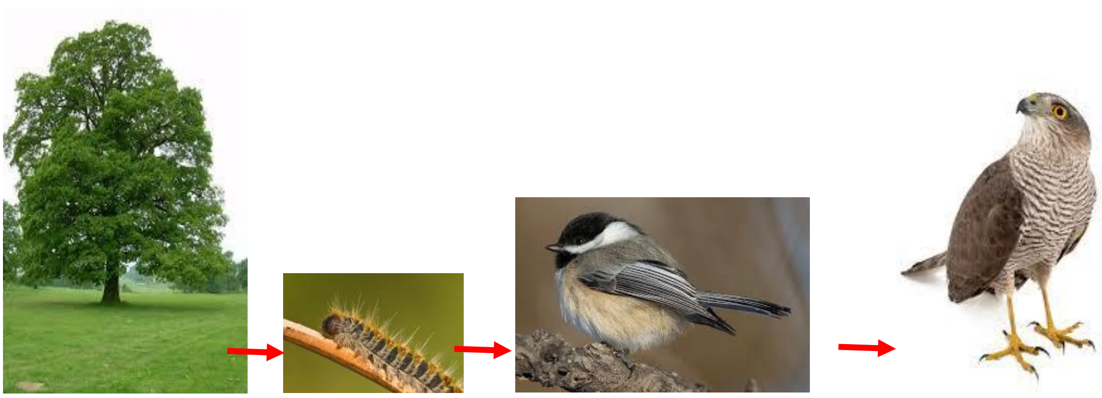
2. Main types of food chain :

2.1. Predator (consumer) food chains:

This type of food chain can be found in all environments where light allows photosynthesis, i.e. the production of organic matter by chlorophyllous plants. The food chain starts with plants, then small organisms and progressively larger organisms.

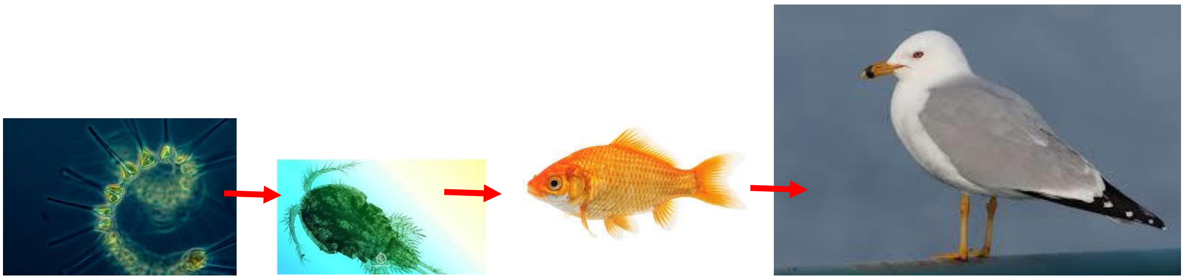
Example:

In a forest:



Oak caterpillar titmouse sparrowhawk

In the marine environment:

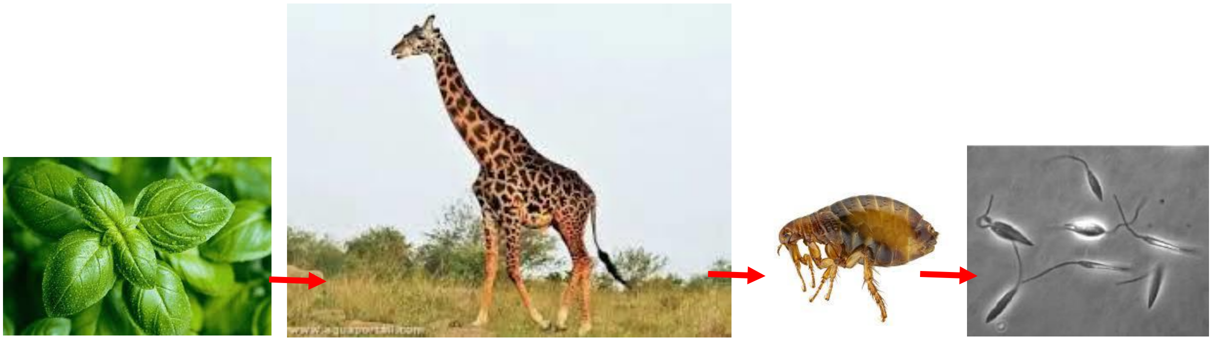


phytoplankton zooplankton fish gulls

2.2 Parasite food chains :

The parasite chain leads to organisms that are increasingly smaller in size and more numerous.

Example:



Grass Herbivorous mammals Fleas Leptomonas

2.3 Saprophytic food chains :

The saprophytic food chain starts with dead, more or less decomposed plant or animal matter (corpses, dead parts, excrement) and spreads to increasingly small (microscopic) and numerous organisms.

Example:

Dead leaves

nematodes

bacteria

Chapter IV: Ecosystem functioning

1. Energy flows in the biosphere :

The Sun is the primary source of energy for the biosphere. Approximately 30% of solar radiation is reflected back into space, 20% is absorbed by the Earth's atmosphere, and the remaining 50% is absorbed by the Earth's surface and converted into heat.

Solar radiation is the main source of energy flow in most ecosystems. Energy flow is the one-way passage of energy through an ecosystem. This flow corresponds to the quantity of energy assimilated by the beings that make it up. As for matter, its circulation in the natural ecosystem is coupled to the flow of solar energy.

Within a food web, the transfer of energy undergoes enormous losses as it passes from one level of production to the next.

1.1. Flows at the level of primary producers (P1) :

For primary producers, energy comes from solar radiation. Of the total light received, only a small proportion is used. Some of the energy absorbed by the plant is dissipated in the form of heat, while the rest is used to synthesize organic matter (photosynthesis). This is gross primary productivity (GPP).

Some of the organic matter produced is lost to respiration (R1). The remainder contributes to net primary productivity (NP).

Part of net primary production is used to increase plant biomass, while the rest represents organic matter available for herbivores.

So the flow of energy through the trophic level of producers is :

$$GPP = NP + R1.$$

1.2 Flows to herbivore consumers (C1):

Only part of the net primary productivity is ingested by herbivores, this is the ingested part (PI1). The other part remains in the biomass of living plants before it is made available to detritivores and decomposers after death. This part is called NU1.

The quantity of energy ingested (PI1) corresponds to what is actually used or assimilated (A1) by the herbivores plus what is not used and rejected in the form of faeces and waste (the non-assimilated part or NA1).

The assimilated part (A1) represents secondary productivity (PS1), which will be used for the metabolism of herbivores, and respiratory expenditure (R2).

So the flow of energy through the herbivore food web is :

$$A1 = PS1 + R2$$

1.3. Flows at carnivorous consumers (C2):

The flow of energy at the level of carnivorous consumers occurs in the same way as that of herbivorous consumers. However, only part of the energy set by primary consumers will be used by carnivores or secondary consumers. This is the swallowed portion of PI2.

After the prey die, due to old age or other causes, their bodies will be available to decomposers. This is the unused part called NU2.

The amount of energy ingested (PI2) is what is actually used or assimilated (A2) by carnivores plus what is unused and released as feces and waste (the unassimilated part or NA2).

The assimilated part (A2) represents on the one hand secondary productivity (PS2) which will be used for the metabolism of carnivores, and on the other hand respiratory expenditure (R3).

Thus, the flow of energy through the carnivorous food web is:

$$A2 = PS2 + R3$$

Detritivores and decomposers play an important role in the energy flow by intervening in the recovery of the energy stored in the unused part (NU1, NU2, NU3,...).

Detritivores and decomposers use the recovered energy for their metabolism and biomass growth. This energy is lost by respiratory catabolism or fermentations.

2. Ecological pyramids, productivity and bioenergy yields:

2.1. Ecological pyramids:

Ecological pyramids, called trophic pyramids or energy pyramids, provide a graphical representation of the structure of the trophic levels of ecosystems. In an ecological pyramid w e have a superposition of rectangles of the same height, but whose length is proportional to th e importance of the measured parameter.

The three main types of ecological pyramids are: the pyramid of numbers, the pyramid of bio mass, and the pyramid of energy.

2.1.1. Pyramid of numbers:

The pyramid of numbers is the number of individuals at each trophic level of an ecosy stem. Most pyramids of numbers are larger at the bottom and smaller at the top, that is, the nu mber decreases when you go back from the producers to the consumers (Fig28.).

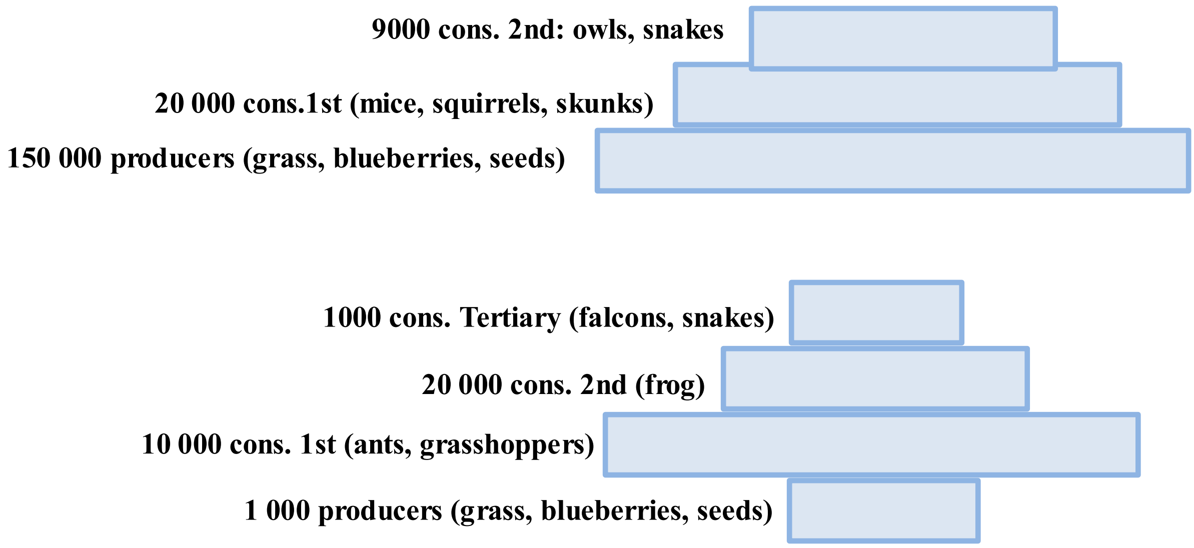


Fig. 28. Example of pyramid of numbers.

2.1.2. Pyramid of Biomasses:

The biomass pyramid expresses the total biomass of organisms at each trophic level in an ecosystem. These pyramids are usually wider at the bottom, meaning there is a progressive reduction in biomass at each successive trophic level. It is estimated that, on average, there is a reduction of around 90% of biomass at each trophic level (Fig.29).

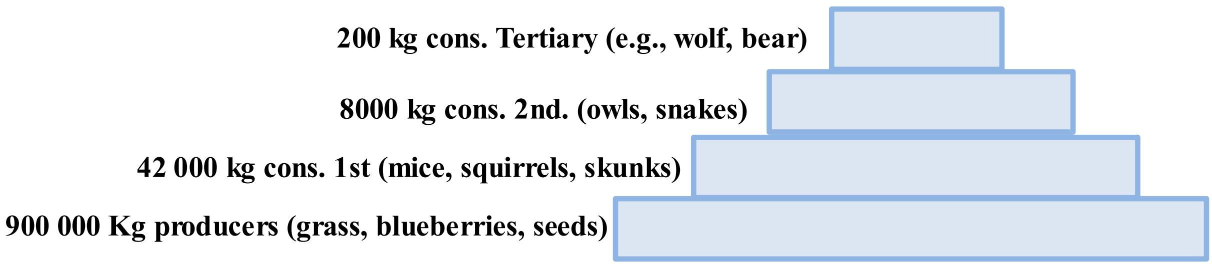


Fig. 29. Example of pyramid of numbers.

In some cases, rapid reproduction produces enough of the organism to feed the predators. This can lead to less biomass at lower trophic levels. This is an example of an aquatic system in which the primary producers are unicellular algae (phytoplankton) and the herbivores are animals the size of a grain of rice (like copepods) that feed directly on the algae cells. Thus, the renewal of algal cells is often rapid, but the consumption by animals is also rapid. Therefore, the biomass of copepods is always higher than that of algae (Fig.30).

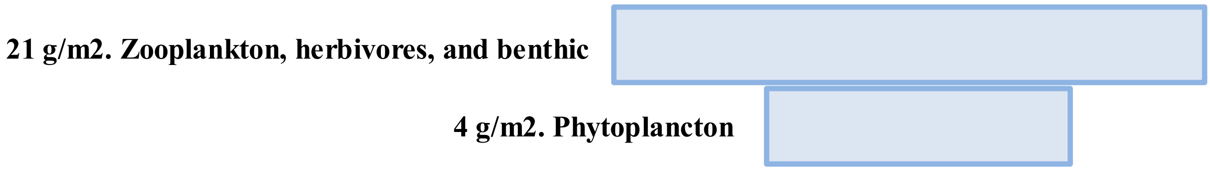


Fig.30. Inverted biomass pyramid

2.1.3. Energy Pyramid:

The energy pyramid shows the amount of energy, often expressed in kilocalories per square meter per year, contained in the biomass of each trophic level of an ecosystem.
These pyramids are always wider at the bottom and gradually become smaller through the successive trophic levels. Indeed, a trophic level could never receive more energy than the level below it contains (Fig31).

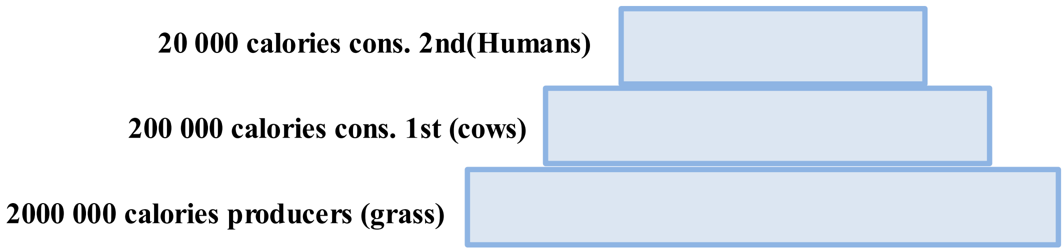


Fig.31. Energy Pyramid.

2.2. Productivities:

2.2.1. Primary productivity:

Gross primary productivity (GPP) is the total amount of carbon compounds produced by the photosynthesis of plants in an ecosystem over a given period. It is generally expressed in tonnes of carbon/hectare/year or in grammes of carbon/m2/day.

Net primary productivity (NPP) is the amount of energy captured by photosynthetic organisms minus the amount expended for cellular respiration and other cell maintenance processes. It is the productivity of plants in continental ecosystems and phytoplankton in the ocean.

So: $GPP = NPP – R$

2.2.2. Secondary productivity:

Secondary productivity is the mass fixed by consumers in their tissues per unit of time and surface area. It always remains much lower than primary productivity. There is only one type of secondary productivity.

The secondary productivity of oceanic zones is particularly more abundant than that in continental ecosystems.

2.3. Bioenergetic yields:

2.3.1. Ecological efficiency:

Ecological efficiency is the ratio between the net production of the consumer and the net production of the consumed trophic level.

$$Rec = (PS1/PN)*100$$

2.3.2. Consumption Efficiency:

The consumption efficiency is the ratio between the energy ingested by a consumer and that contained in the food available to it.

$$Rex = (I1/PN)*100$$

2.3.3. Assimilation Efficiency:

The assimilation efficiency is the ratio between the energy assimilated from nutrients and the energy ingested from food. Indeed, some consumers are thrifty while others are wasteful.

$$Ra = (A1/I1)*100$$

Example:

– 80% in carnivores,

– from 15 to 75% in herbivores,

– 5 to 10% in detritivores (pseudoscorpions, millipedes…) and geophages (earthworms…).

2.3.4. Net production efficiency:

Net production efficiency is the ratio of net production to assimilated energy, expressed as a percentage:

Net production efficiency (Rp) = (Net production / Assimilated energy) * 100

3. Circulation of matter in ecosystems and main biogeochemical cycles:

Biogeochemical cycles are processes of transport and cyclical transformation of elements (carbon, nitrogen, phosphorus, sulfur, etc.) or chemical compounds between soils, atmosphere, and hydrosphere, within which the biosphere exists. These cycles facilitate the transformation of materials from organic to mineral forms within the biosphere.

We can distinguish three major types of biogeochemical cycles:

- Water cycle,
- Cycle of elements with a predominant gaseous phase,
- Cycle of elements with a predominant sedimentary phase.

3.1. Water Cycle:

- **Evaporation**: A portion of seawater and ocean water evaporates under the action of the sun to form clouds. These clouds are transported by winds over the continents, where they gather with existing clouds (Fig. 32).
- **Precipitation**: **It occurs as rain, snow, or hail. Part of this water returns to the atmosphere more or less quickly via evaporation or transpiration by plants and animals**.
- **Runoff**: Water flows over the ground surface, reaching rivers and streams, and eventually returning to the sea.
- **Infiltration**: Remaining water seeps into the ground and is stored in aquifers, from where it may eventually return to the sea.

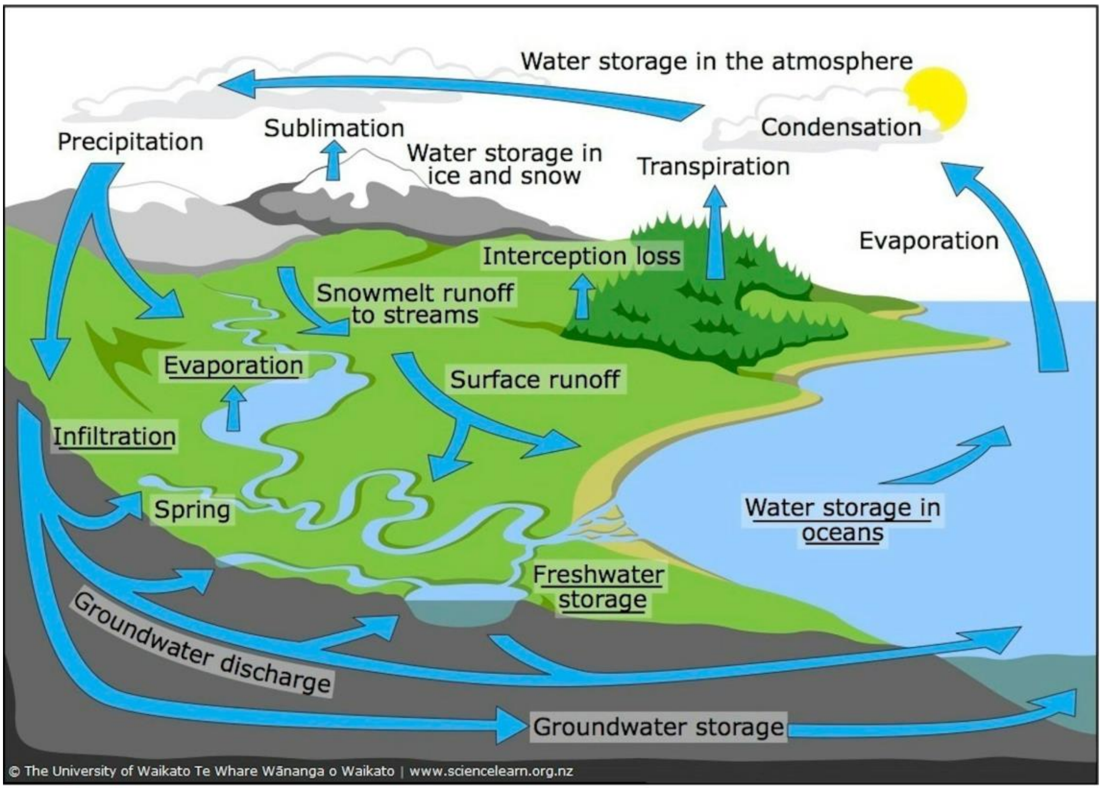


Fig. 32. The water cycle (https://www.sciencelearn.org.nz/images/807-the-water-cycle)

3.2. Biogeochemical cycles in the gaseous phase:

3.2.1. Carbon Cycle:

The carbon cycle is a succession of phenomena alternating between the photosynthesis or chemosynthesis of organic carbon from mineral carbon, and the production of mineral carbon from organic carbon through respiration, fermentation, or combustion.

The carbon cycle is a good example for understanding the relationship between the different Earth spheres (Fig.33).

The main carbon reservoirs are:

• The atmosphere: 700 Gt (in the form of carbon dioxide CO_2 and methane CH_4)

• The oceans 40,000 Gt (in the form of dissolved CO_2 and bicarbonate ion HCO_3^-)

• Soils and the biosphere: 2,000 Gt (in the form of organic C)

• The rocks of the crust: 50,000,000 Gt (in the form of carbonates, mainly $CaCO_3$)

• Fossil organic matter: 13,000,000 Gt (in the form of organic C)

There are flows between the reservoirs and the responsible processes. We can mention:

-Between the atmosphere and the biosphere:

Photosynthesis: in terrestrial environments, land plants capture atmospheric carbon dioxide (CO_2) and transform it into glucose ($C_6H_{12}O_6$).

Respiration: Living beings use $C_6H_{12}O_6$ and produce CO_2 during cellular respiration.

Decomposition: Decomposer organisms (e.g., fungi) break down the waste and corpses of living beings. This produces CO_2 and methane (CH_4).

Combustion: The combustion of organic matter by forest fires produces CO_2.

-Between the hydrosphere and the biosphere:

Photosynthesis: In aquatic environments, aquatic plants capture the CO_2 dissolved in the water and transform it into $C_6H_{12}O_6$.

-Between the biosphere and the lithosphere:

Formation of fossil fuels: The waste and corpses of living beings buried in the ground can, after several million years, transform into fossil fuels, such as oil, coal, and natural gas.

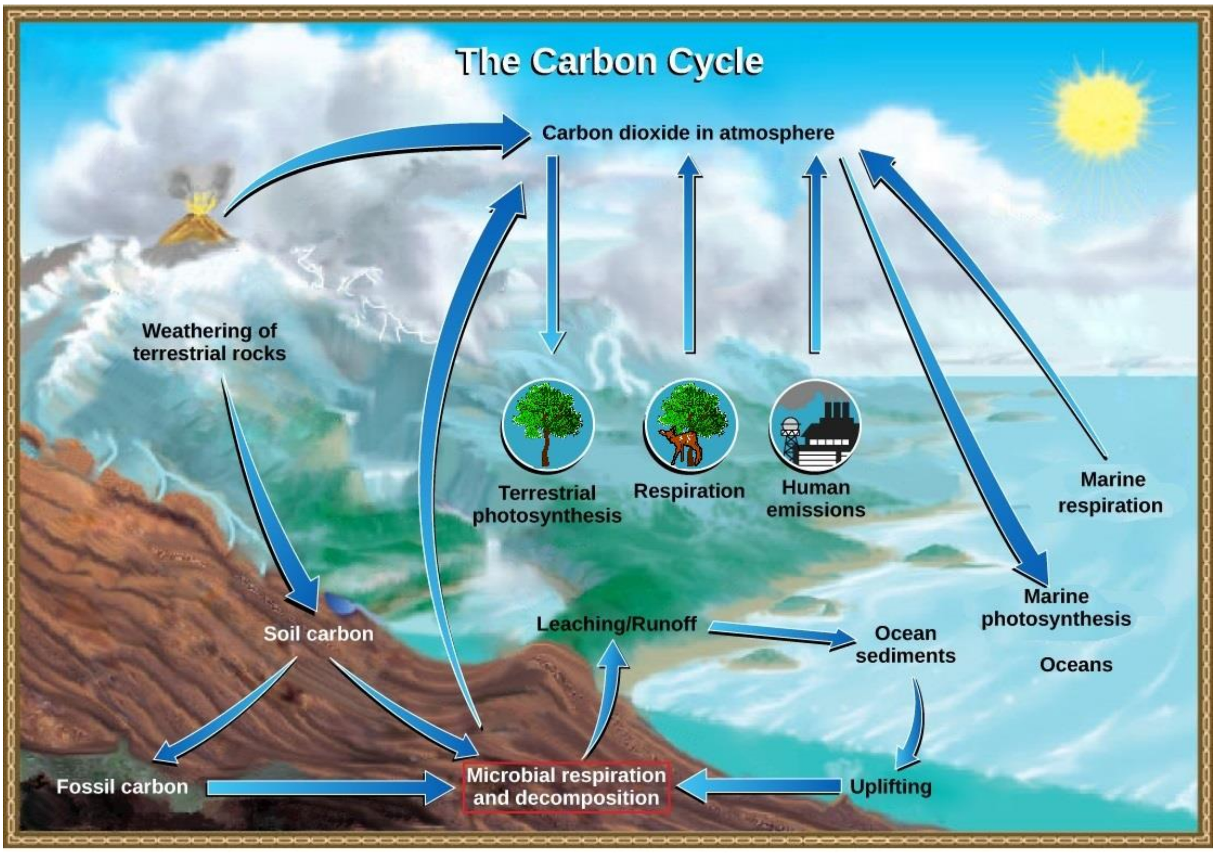


Fig. 33. The carbon cycle (https://www.teachengineering.org/lessons/view/cub_carbon_lesson01)

3.2.1. Nitrogen Cycle:

Nitrogen is the most abundant element in the Earth's atmosphere (78%), where it is found in its normal diatomic molecular form, N2.

The transformation of atmospheric nitrogen (N2) into an assimilable form requires several processes (Fig.34). It involves:

Fixation: it is the conversion of atmospheric nitrogen into nitrogen usable by plants and animals. It is carried out by certain bacteria that live in the soil or in water and that manage to assimilate atmospheric nitrogen N2. It particularly involves cyanobacteria and certain bacteria living in symbiosis with plants (among others, legumes).

Nitrification: it is the second stage of the nitrogen cycle. A portion of the ammonia produced during the nitrogen fixation stage is used by bacteria present in the soil to produce nitrite (NO2-). Nitrite can then be converted into nitrate (NO3-), which also contributes to plant growth.

Denitrification: In the absence of oxygen (soil compaction or stagnant water), denitrification phenomena occur, producing nitrous oxide (N2O), nitric oxide (NO), or dinitrogen (N2) from ammonium. Denitrification is therefore an anaerobic process.

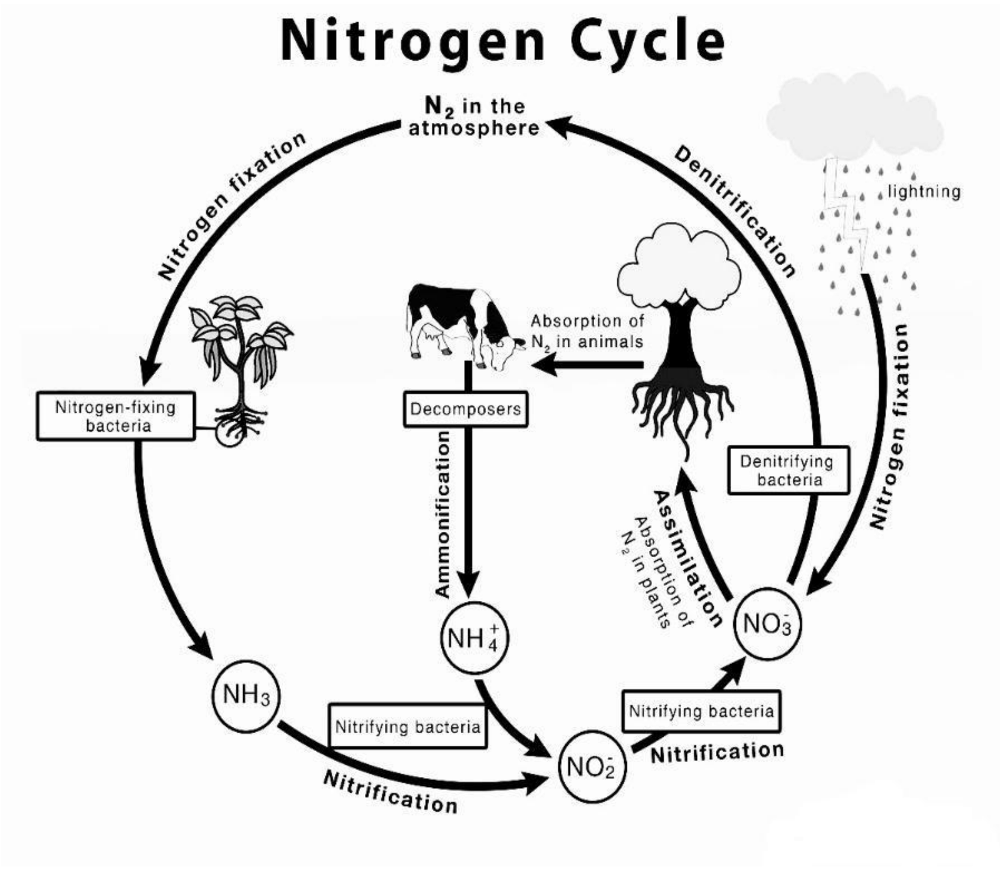


Fig.34. Nitrogen Cycle (https://unacademy.com/content/neet-ug/study-material/chemistry/what-is-nitrogen-cycle/)

3.3.Biogeochemical cycles in the sedimentary phase:

Phosphorus Cycle:

The phosphorus cycle is relatively complex. The inputs into the soil are mainly due to mineral and organic contributions. The losses are mainly due to agricultural exports and erosion (leaching is marginal).

In the soil, phosphorus is of both organic and inorganic nature. Phosphorus is associated with soil particles (particulate phosphorus). It is also present in soluble form (soluble phosphorus) in the soil solution, in small quantities. It is circulated through leaching (or erosion) and dissolution, which introduce it into terrestrial ecosystems where it is absorbed by plants.

In water, different processes of transformation of soluble and particulate phosphorus occur depending on the environment:

In freshwater, the assimilation of soluble phosphorus is indeed more or less strong depending on the intensity of biological activity. According to Dorioz et al. (1997), particulate phosphorus can either interact with phytoplankton to be assimilated or sediment.

In marine waters, the orthophosphate ion constitutes the bulk of the dissolved mineral form that will be directly assimilated by phytoplankton and macroalgae.

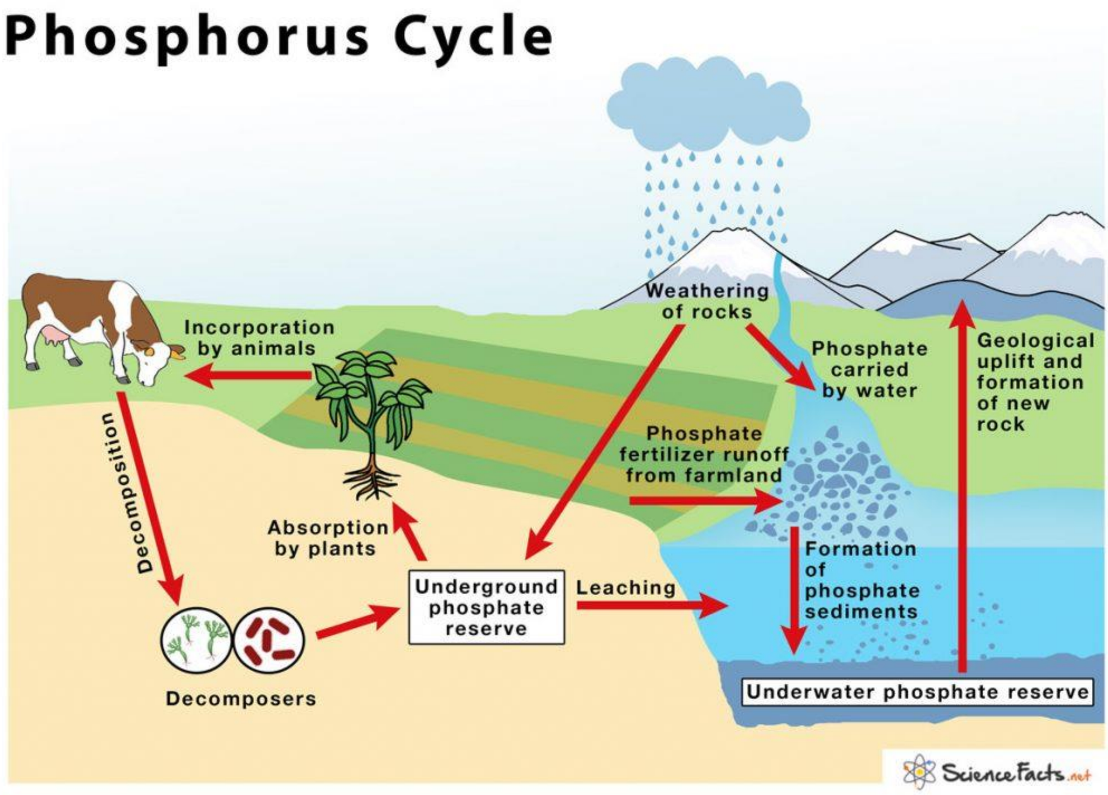


Fig.53. Phosphorus Cycle (https://www.sciencefacts.net/phosphorus-cycle.html)

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