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Introduction to ecology from a biological point of view

Definition

Ecology is defined in the natural sciences as the interactions/relationships between living organisms and their inanimate environment on the one hand, and between living organisms themselves on the other. All factors influence each other continuously.
Cycles are essential.
In intact ecosystems the cycles are closed, in disturbed ones they are temporarily or permanently open. After some time, many cycles close again with different parameters. For many species, this can take a very long time or too long to save them from extinction.

What does it mean in ecology...?

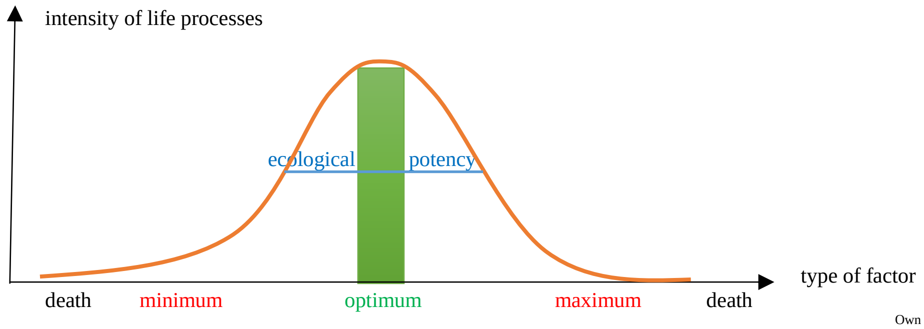
abiotic	not dependent on/ influenced by living beings
adaptation	change of a living being in the course of many generations triggered by changing environmental factors (mutation and selection).
alternate-humidity plants	have a different moisture content depending on the momentary environment
alternating-warm animals	Their body temperature must adapt to the ambient temperature.
species with a constant body temperature	don’t change their internal temperature.
autotrophic organisms	They build up organic compounds as producers from light energy by photosynthesis or from chemical energy by chemosynthesis.
biocenosis	living beings of different species populating a biotope
biomass	Newly formed biological material per unit time (number of organisms, cells...).
biome	is dynamic biological system. Natural disturbances are the rule. → Flow equilibria.
biosphere	totality of all ecosystems
biotic	dependent on or influenced by living organisms.
biotope	habitat for a population or/and a biocenosis
climax	High state or end state of an ecosystem
competition avoidance	Competition reduction Strategy to allow 2 species with originally equal demands to survive in the same biotope.
competitive exclusion	2 species exclude each other in a biotope.
destructors	They decompose organic material to release energy. Minerals are also released in the process.
dry-air animals	have evaporation-inhibiting facilities
ecological niche	system of interactions between organisms of a population and their environment
ecosystem	entirety consisting of biocenosis and biotope

equi-warm animals	Their body temperature is constant and not dependent on the ambient temperature.
flow equilibrium or dynamic equilibrium	The equilibrium is not static. It moves within systemic limits.
gross primary production	formation of new biomass within a defined period of time
heterotrophic organisms	As consumers, they feed on organic material, so they are directly or indirectly dependent on producers.
hibernation	hormonally controlled lowering of body temperature in animals of the same temperature to slow metabolism to counter seasonal food shortages
interspecific	interactions between members of different species
intraspecific	interactions between members of the same species
long day plants	need as a trigger for flowering, depending on the species, certain lengths of day.
maximum	just tolerable upper value for an environmental factor
mimicry	mock warning habit acquired by "imitating" a dangerous, inedible or poisonous species
minimum	just tolerable lower value for an environmental factor
modification	An individual creature changes its appearance or parts of its appearance according to environmental factors within the genetically given possibilities. *Example:* *The same grass species (annual bluegrass, Poa annua) grows up to 50 cm tall at 600 m above sea level and a few cm tall in the high mountains.*
moist animals	need a moist environment. They don’t have any desiccation protection.
neobiota	alien plant species (neophyta) or animal species (neozoa) If they displace original species, they are invasive. *Examples for Switzerland:* *mugwort (ambrosia artemisiifolia).* *cherry laurel (prunus laurecerasus),* *asian ladybug (harmonia axyridis)* *wandering mussel (dreissena polymorpha)*
optimum	best possible value of an environmental factor
osmoregulation	regulation of body fluid by a concentration balance
parasitism	An organism benefits unilaterally from the host organism.
pH- value	acidity or alkalinity of a fluid amount of H_3O^+- ions in the **solution** pH 0- 6.9 acidic: more H_3O^+ than OH^- pH 7 neutral: same amount of H_3O^+ as OH^-, (10-7 mol/l of each) pH 7.1- 14 basic: more OH^- than H_3O^+.
pheromone	signaling substance

pointer organisms	indicate a high value (quantity) of an environmental factor by their presence in a biotope
population	living organisms of a species living in a defined habitat
population density	number of organisms in a population per defined unit of biotope
Reaction rate- temperature- rule (RRT-rule)	Rule of thumb: When the temperature is increased by 10 degrees, the reaction rate doubles.
self-moist plants	have water storage devices
short-day plants	need dark periods of more than 12 h as a trigger for flowering. They bloom in winter or spring.
species	The individuals of a species can reproduce among themselves. Interspecific reproduction is not possible, apart from a few exceptions. Their offspring, however, are not capable of reproduction. Several races can be found in a species.
succession	Populations are following each other in a newly colonized ecosystem.
symbiosis	Both/all organisms involved benefit from each other and are often interdependent.
tolerance range	range of an environmental factor tolerated for a particular living organism. It lies between minimum and maximum of this factor for a certain living being. These values are species-specific!

Environmental factors

Tolerance range



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The tolerance range starts at the minimum and ends at the maximum.

The tolerance range is specific for each factor and for each species.

The same is applied for the location of minimum and maximum, as well as for the range of optimum and ecological potency.
The range of ecological potency lies within the tolerance range and shows in which span width the species is viable.
If it falls below the minimum and exceeds the maximum, the species cannot survive.

Adaptations of species to changing environmental factors are possible with evolution over many generations.
Modifications are possible in the same individual within its genetically predetermined range.

Example:
In corn, the tolerance curve for temperature is further to the right than that of its parasite, the European corn borer. This means that the European corn borer can become a pest of corn crops, especially in cool, humid summers. Mediterranean climates or hot dry summers reduce parasite infestation.

→<u>Law of effect</u>
The growth/development of a species is governed by the factor furthest from the optimum.

Abiotic factors

<u>Temperature</u>

RRT (reaction rate-temperature) rule

The chemical reaction rate even for living systems depends on temperature.

Elevation levels

The composition and type of vegetation change with increasing altitude above sea level and with increasing north/south latitudes.
In areas around the Arctic Circle, we find vegetation similar to that found in high alpine regions.

Leaf fall

is found in many plants in temperate zones. The connection between leaf and branch is actively closed by the plant and leads to the decomposition of chlorophyll. This causes the leaves to become yellow or red and dry out. The liquid is returned to the stem and root. This prevents the water in the cells from freezing in cold conditions, often irreversibly damaging the plant.
Examples: Deciduous trees and shrubs

Alternately warm animals

must adapt their body temperatures to the ambient temperature.
All animal groups except birds and mammals.
→ Cold and heat torpor.
At the minimum, animals fall into a cold torpor,
At the maximum, they enter a heat torpor.
Example: flies

Animals with a constant body temperature

Mammals and birds have a constant body temperature.
Activity is adapted to the food supply, especially in non-tropical areas.

→ Bird migration
Migratory birds follow the food supply
Examples: Starlings, swallows

→ Hibernation
Body temperature is directly hormonally and indirectly controlled by the outside temperature. The body temperature sinks.
Example: alpine marmot (marmota), bats (microchiroptera)

→ Hibernation
Body temperature does not sink, but animals sleep deeply and for long periods.
Examples: brown bear (ursus arctos), squirrel (sciurus vulgaris).

Bergmann's rule

Individuals of one or of closely related species with a constant body temperature become larger in colder regions than in warm regions.

Reason: The mass is larger in relation to the surface and therefore better protected against warmth loss.

Example: emperor penguins (aptenodytes forsteri) grow up to 125 cm, galapagos penguins (spheniscus mendiculus) about 50 cm.

Allen's rule

Individuals of a species with a constant body temperature have larger body appendages in warm regions than in cold ones.

Reason: Heat dissipation in warm regions is improved and warmth loss in cold regions is reduced.

Example: The red fox (vulpes vulpes) has smaller ears than the desert fox (vulpes zerda).

Water

Osmoregulation

The water content in the cells is regulated by the concentration of the substances in the body fluids.

Special case: animals living in salt and fresh water need special adaptation mechanisms

Example: Salmon migrate from the sea to their home rivers to spawn.

Adaptations of plants

These occur in the course of evolution over many generations.

In alternate-water plants, cells lose fluid during drought and reduce or stop metabolism. When enough water is available, the cells swell and become active again.

Examples: mosses, lichens

Equally or intrinsically moist plants have protective devices against water loss, either in their anatomy (thick cuticle on leaves) or by being able to close stomata. The reduced photosynthetic rate is often compensated by a more efficient mechanism (C4 instead of C3).

Examples: grasses

Xerophytes (dry plants)

are adapted to drought by several features: thick cuticle, thickened leaves and shoots (succulents), or transformation of leaves into spines

Example: cacti

Hygrophytes (moist plants)

need moderately moist to humid sites for growth

Example: ferns

Hydrophytes (water plants)

They lack stomata on the submerged parts of the plant. They absorb water and mineral salts over their entire surface.

Examples: water lily (ninfea comune), algae

Tropophytes (versatile plants)

live in temperate climates and have adapted to unfavorable seasons: fall foliage in autumn

Examples: deciduous trees and shrubs

Some plant species can survive extreme dry periods desiccated.

Examples: rose of Jericho (anastatica hierochuntica), lichens.

Some species even need bushfires to continue growing or sprouting.

Example: Eucalyptus trees

Adaptations of animals

Many animals regulate humidity to a certain extent through their skin. Diverse adaptations especially to drought protect against water loss.
Examples: scales of reptiles, chitinous armor in insects

→Dry rigidity

Occurs at the maximum value for dryness for the corresponding species.
Example: tardigrades (tardigrada).

Light

Photoperiodicity

Growth and behavior are controlled by light-dark phases. → internal clock.

Plants

- Open and close flowers depending on time of day.
  Example: dandelion (taraxacum officinale)
- or they may lower the leaves depending on the time of day.
  Example: certain bean plants
- or turn the flowers according to the sun.
  Example: sunflower (helianthus annuus)

Animals are divided into

- day active
  example: many bird species, many species of insects
- crepuscular
  example: roe deer (capreolus capreolus), hedgehog (erinaceus europaeus)
- Nocturnal
  example: bats (microchiroptera), wild boars (sus scrofa)

This behavior protects them from predators or gives them a hunting advantage.

Bird migration is also controlled at least in part by light.

Adaptations of plants

light plants

They need a lot of light and usually have small thick leaves.
Example: grasses

shade plants

They need little/er light and have mostly large thinner leaves.
Example: ferns

long day plants

They develop flowers as the day length increases.
Example: irises (iris spec.)

short-day plants

They only begin to bloom when the days become shorter.
z. e.g. asters (aster spec.)

day-neutral plants

The length of the day has no influence on flower formation
Example: shepherd's purse (capsella bursae pastoris), maize (zea maïs)

Modifications in plants

With the same genetic makeup, they form larger or smaller leaves depending on the amount of light available to make the best use of light

Light leaves are smaller and thicker than shade leaves.

Adaptations of animals

Animals are indirectly dependent on light especially for plant food.
→ Adaptation to the changed diet, especially essential for food specialists.

pH value and calcium content

Plants in particular are dependent on the acidity of the soil, as they are bound to a fixed location. This is more or less specific for each plant species.
Acidic soils often contain small quantities Ca, Mg or K.
Al_3^+-, $Fe^{2+/3+}$ - and $Mn^{2+(7,6,4,3+)}$ - salts are more soluble in acidic soils and can be toxic to individual species.
Some plants can only tolerate a very narrow pH range, others are more flexible, but usually have a preferred pH range.
Calcareous soils are more alkaline.
Example: Hydrangea (Hydrangea spec.), mountain ash (Sorbus acuparia) grow in more acidic soils.
Example: field mustard (sinapis arvensis), corn poppy (papaver rhoeas)grow rather on alkaline, calcareous soils.

Climate change - coral mortality

warmer seas → more CO_2 dissolved in water → more H_3O^+ in water → pH decreases.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$
$$H_2CO_3 \rightleftharpoons HCO_3^- + H_3O^+$$

The degree of saturation of lime ($CaCO_3$) in surface water is important for marine organisms that require lime for their development.
The reaction with H_3O^+ solve calcium carbonate, which corals need for their formation, in the seawater. (The chemical equilibrium shifts towards Ca^{2+} ions)
$CaCO_3 + 2\ H_3O^+ \rightleftharpoons Ca^{2+} + CO_2 + 3\ H_2O$ (incomplete equation)

Salinity of the soil

There are salt-loving, salt-tolerant, and salt-fleeing species.
Salt-loving plants have often developed mechanisms (salt glands) to excrete excess salt.
Example: Mangroves form a large group of plants that include many families: 2 important genera are Avicennia and Rhizophora. They are mostly typical halophytes with adaptations to salinity and variable water level in muddy soil (aerial roots).

Oxygen and carbon dioxide

Oxygen (O_2) is important for energy release from sugars (glucose $C_6H_{12}O_6$) in cellular respiration.
CO_2 is necessary for energy binding in the form of glucose by photosynthesis. O_2 is released during this process.

→Pointer organisms

indicate a high value (amount) of an environmental factor by their presence in a biotope.

Biotic factors ← relationships among living organisms

Relationships between the species

relationships of living organisms of one species

Plants: Their communication is still poorly understood.
Animals: → behavior

Pheromones

are messenger substances. They control reactions between animals and probably also between plants.

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→ Intraspecific competition

competition by individuals of the same species for resources such as food, space, reproductive partners....

→ site utilization in plants

→ behavioral processes in animals

<u>Interspecific relationships</u>

→interspecific competition

Different individuals of different species compete and the same resources, such as food or space.

→ competitive exclusion.

Different species with the same requirements cannot occur in the same habitat. They displace each other.

Examples: invasive neophytes or neozoa.

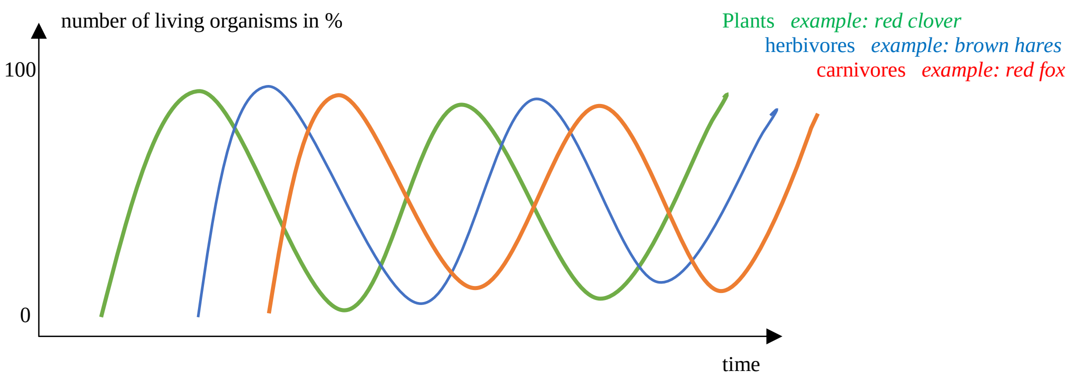
→ competition avoidance/reduction.

Species with very similar demands on environmental factors live in different locations (plants) or in different habitats (animals).

Example: chamois (rupicapra rupicapra) and roe deer (capreolus capreolus) live at different altitudes.

→Predator-prey relationship.

A wide variety of relationship types are possible.



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First the plants increase, then the herbivores and at the end the carnivores.
Many herbivores decrease the food plants. At the same time the supply of food for the carnivores increases. So herbivores decrease, the plants recover, then carnivores decrease, and the herbivores recover....

Animal's attack or escape

If the escape distance (according to H. Hediger, Swiss zoologist) is undercut, flight usually occurs. It is usually more energy efficient than attacking.
Attacking occurs when the escape distance/individual distance is more a less massively undercut. If mother animals lead young, the critical distance is usually larger.

Defense

active defense

is always more energy consuming than escape. It is usually used by animals give predators and to protect the young (in brood care).

Behavior: biting, poking, hitting, scratching, stinging....
until the predator gives up or the strength decreases.

passive defense

can be used by plants and animals.

Resources:
- Poisons on the surface or in the organism
  example: snakes
- stinging hairs
  example: nettles (urtica)
- spines (outgrowths of the epidermis)
  example: blackberries (rubus)
- thorns (transformed leaves or parts of the shoot)
  example: cacti
- malodorous secretions,
  example: lama

Protective habits

camouflage

Coloration adapts to the environment.
example: Snow hares (elpus timidus), in summer brown spotted, in winter white)

warning habits

yellow-black or orange-black, warn the predator
example: Fire salamander (salamandra, salamandra), wasps

fright habits

conspicuous body markings that imitate the eyes of a large animal when moving, for example
example: Wings of the butterfly peacock butterfly (inachis io)

mimetic habits

mimesis

imitate the environment
example: cacti "living stones"

mimicry or mock warning habits

imitate the body coloration of an animal with warning costume

- defensive: serves as protection against predators
  Example: The hoverfly (episyrphus balteatus) imitates the appearance of wasps)

- aggressive: imitates the appearance of a harmless animal/plant and gets to the prey more easily
  Example: The predatory sabre-tooth blenny (Aspidontus taeniatus) imitates the harmless cleaner wrasse (Labroides dimidiatus).

Parasitism

Coexistence of two species, but only one species is benefiting.
The parasite lives in or on the host organism and damage it to a greater or lesser extent. Certain parasites also have several hosts, so-called intermediate hosts. Most parasites are more or less specific.

The transitions to symbiosis (see below) can be fluid.
Example: Codling moth (cydia pomonella) in apples (Malus domestica): the wormy apple ripens earlier, which can be an advantage in a cold autumn.

- Endoparasites live inside the host and often have reduced body parts.
  Example: Malaria pathogen plasmodium with the intermediate host fever mosquito (anopheles).
  Modern viruses are obligate endoparasites. For their reproduction they need a living host organism.

- Exoparasites live on the host organisms.
  Example: Mosquitoes, fleas, ticks

Carpose

One-sided beneficence
One species has an advantage from living together, the other neither advantages nor disadvantages. Often the transitions to parasitism are fluid.
Example: barnacles (sessilia) on humpback whales (megaptera novaeangliae)

Commensalism

("commensalism" from Latin commensalis, table companion).
The commensals feed on the same food.
Example: Different vulture species feed on the same carrion. Black vultures (aegypius monachus) open the dead animals and eat skin, tendons, muscles, griffon vultures (gyps fulvus) the innards, bearded vultures (gypaetus barbarus) eat mainly bones and marrow, and Egyptian vultures (neophron percnopterus) the remains of the others and thus eliminate the carcass.

Symbiosis

Cohabitation of two or more species in which all benefit.

- endosymbiosis
  One symbiont resides in the organism of the other.
  Examples: Human microbiome (bacteria in the digestive tract).
  Lichens, consisting of one species of algae and one species of fungi
  Nodule bacteria (Hyphomicrobiales) in the roots of leguminosae

- ectosymbiosis
  The symbionts live outside the body of the symbiotic partner. They are permanently or temporarily in contact with each other.
  Example: Aphids and ants
  Sea anemones (actinaria) and hermit crabs (paguroidea). Ice hermit crabs colonize empty snail shells. The sea anemone attaches to the snail shell of the hermit crab and is thus transported to other food sources. In return, it offers the crab protection from predators with its poisonous tentacles.

Coevolution

adaptation of two or more species to each other over generations.
It can occur in all species and all types of interspecific relationships.
Examples: human being (homo sapiens)- coronavirus (sars-cov-2)
Reproductive cycles of sea anemone (actiniaria) and hermit crab (paguroidea).

Populations

A group of organisms of one species living in the same biotope is called a population.

population density

It is defined as the number of living organisms of a species, the members of a population in a given biotope.

birth rate

number of births within a population in your defined time period

mortality rate

number of living beings of a population that die within a given period of time

regulation of the population

density-independent factors

This factors are influenced by population density.

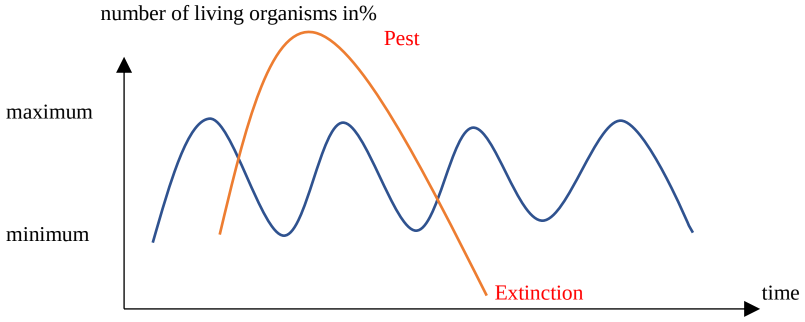
Examples: Climate, food quality, non-specific enemies

density-dependent factors

Factors that affect the population independent of population size.

Examples: Species-specific diseases, density stress, scarce resources

In an ecosystem in dynamic steady state, population numbers fluctuate between minimum and maximum. These values are species specific.



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The population is in a dynamic steady state

The population first becomes a pest and then dies out. Reason: shortage of resources until disappearance.

A species becomes a pest when the number of living beings of this species exceeds the maximum. Basically, any species can become a pest.

Ecosystems

ecological niche

environmental conditions with specific living conditions that are used by individual populations or usually by groups of populations

→ system of interactions between organisms of a population and their environment.

comparison: The habitat is the address of an organism.
The niche is the occupation of this organism

Example: a tree canopy: The tree is a habitat and has as its occupation the maintenance of living conditions (oxygenation, shade...).

Organisms with comparable demands occupy comparable ecological niches.

Example: Penguins (sphenisciformes) in the southern hemisphere and alcids or guillemots (alca) in the northern hemisphere.

ecological equivalents

Creatures from different families have comparable ecological requirements. Often, they arise by convergent evolution (evolution in different species runs independently of each other in the similar direction).

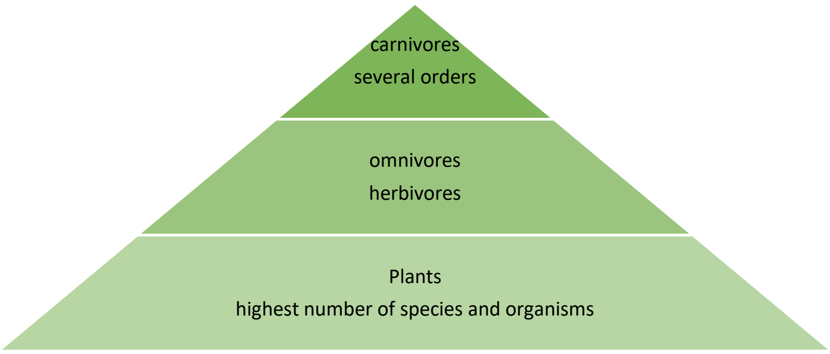
Example: kangaroos (macropodidae)in Australia, desert jumping mouse (jaculus) from Asia and jumping hare (pedetes) in Africa as jumping herbivores
spurge family (euphorbiacea) and cacti (cactaceae).

→ Food relationships

food chains: they run in one direction. However, the term is inaccurate. Better:

food cycles: they consist of several links, usually starting from one species. In an intact ecosystem, these cycles are. The various food cycles interlock.

food pyramid



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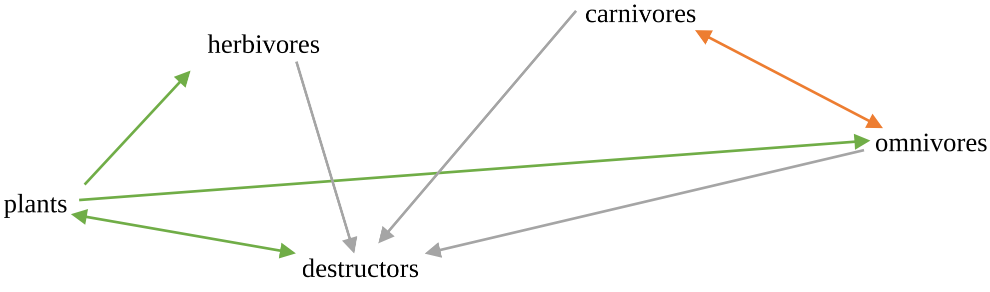
Biomass diminish from bottom to top.

→ Accumulation of toxins from bottom to top
Example: DDT in the fat of polar bears

→ Accumulation of pollutants in the different food cycles, i.e. also in the food nets.

→ **FOOD NETS**



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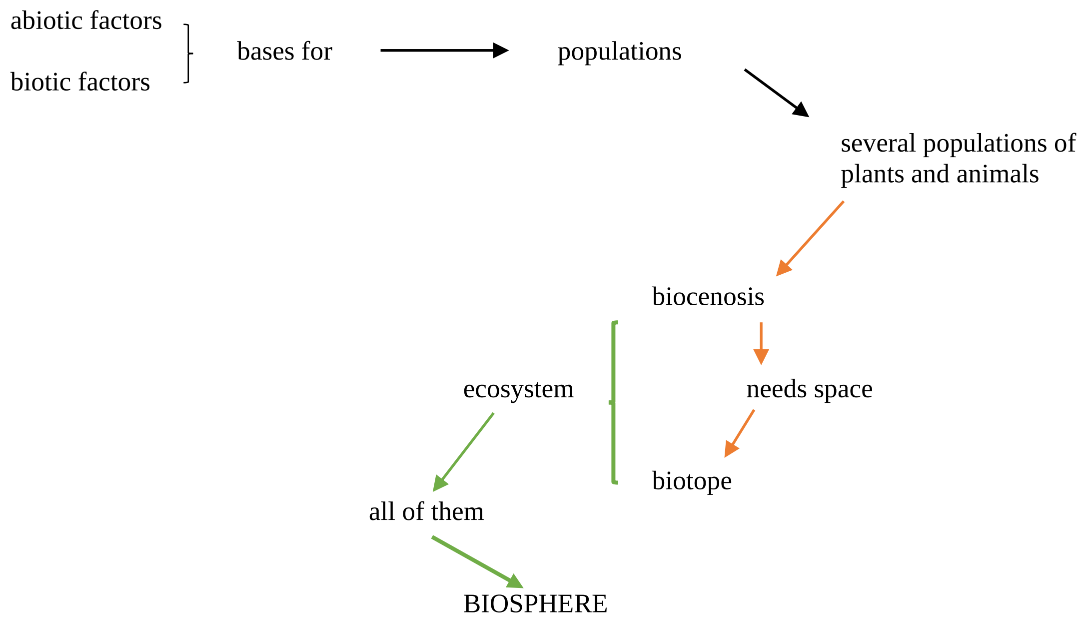
Producers — can metabolize inorganic substances like CO_2 and H_2O to organic substances. For this they need mineral salts. (Photosynthesis)
They are autotrophic.
Green plants, certain bacteria, algae

Consumers — need organic substances for nutrition.
Several orders
They are heterotrophic
Animals, fungi

Destructors — decompose dead organic matter, releasing CO2 and minerals.
They also are heterotrophic.
Soil bacteria, fungi, detritus (=waste) eaters.

Diagram of ecological relationships



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Self-supporters = autotrophic organisms
Non-self-sufficient organisms = heterotrophic organisms

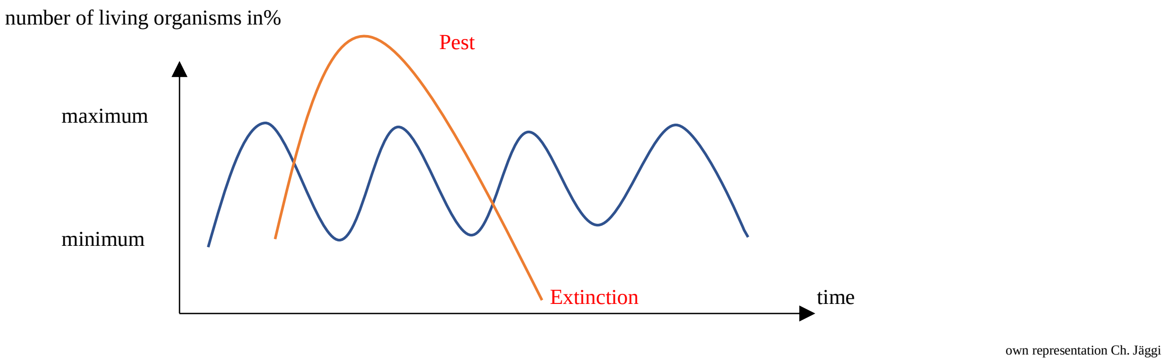
tolerance-
optimal
minimal } conditions
maximal
range

→ Adaptation of the species by mutation over the course of many generations. (evolution)

Modification: concerns an adaptation of an **individual** organism.
The organism changes its appearance or parts of its appearance according to environmental factors within the genetically given possibilities.
Example: The same grass species (annual bluegrass, poa annua) grows up to 50 cm tall at 600 m about the sea level, and a few cm tall in the high mountains.

Biological equilibria

These are flow equilibria. The number of individuals fluctuates within certain species-specific limits. The decisive factor in each case is the corresponding environmental factor.



The population is in a dynamic steady state

The population first becomes a pest and then dies out. Reason: shortage of resources until disappearance.

A species can become a pest when the number of living beings of this species exceeds the maximum. Basically, any species can become a pest.

→ Imbalances

These can be reversible or irreversible.
Irreversible imbalances often result in the extinction of single, but usually several species.

Often **new flow equilibria** are established, not infrequently with a different composition of species.

succession: succession of species after a disturbance of the biological equilibrium or at the beginning of the formation of a new ecosystem.
Example: development of an ecosystem on a newly formed volcanic island (Surtsey, Iceland).

→climax: final stage of an ecosystem under the given site and climate conditions.

Material cycles and energy flow

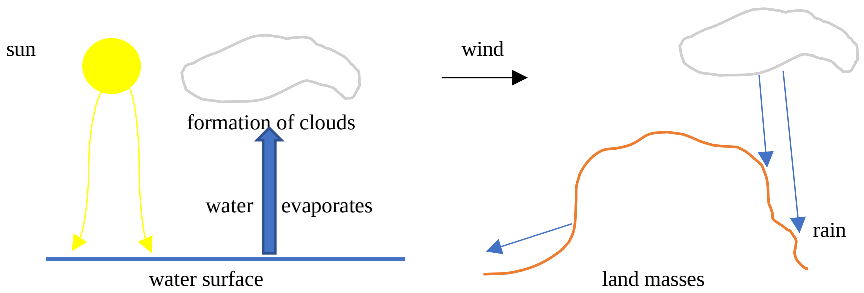
Ecosystems obey thermodynamic laws. Energy cannot be gained or lost. Energy can be converted: sunlight into chemical energy. All energy conversion processes release energy in the form of heat. Energy can be stored in form of sugar, stark, fat or proteins.

Autotrophic organisms - convert light energy into chemical energy through light energy or chemical energy (photosynthesis).
Examples: Green plants, algae, cyanobacteria
- or they use energy released by inorganic reactions such as oxidation reactions to produce organic molecules such as glucose (chemosynthesis).
Examples: Bacteria that carry out chemosynthesis

Heterotrophic organisms need organic material for nutrition.
Example: animals, mushrooms

Chemical elements are constantly reintroduced in the material cycles

Water cycle



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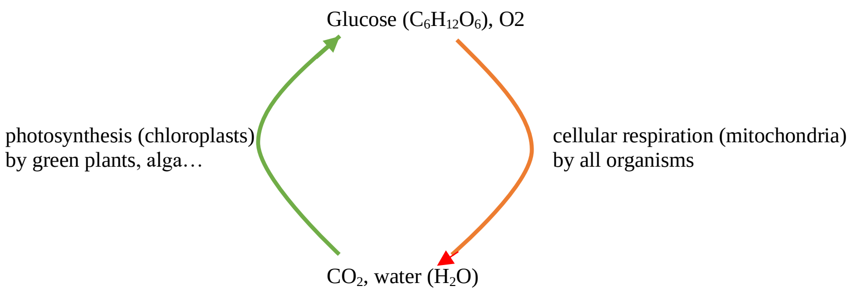
Oxygen - carbon cycle



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Photosynthesis splits water with the help of chlorophyll. (Photosystems I and II) Light energy is converted into chemical energy. O2 is released. CO2 is incorporated into the sugar precursor via the Calvin cycle. Glucose is formed and later linked to starch (amylose and related products). The chemical energy is stored.

During cellular respiration, glucose is cleaved by glycolysis and Krebs cycle. Energy and electron carriers (ATP and NADH + H+) are loaded. CO2 is released as a degradation product. O2 reacts with hydrogen (4 H+ + 4e-) in the respiratory chain to form water.

Burning of organic matter, volcanic eruptions and melting of permafrost also release CO2.

Cellular respiration

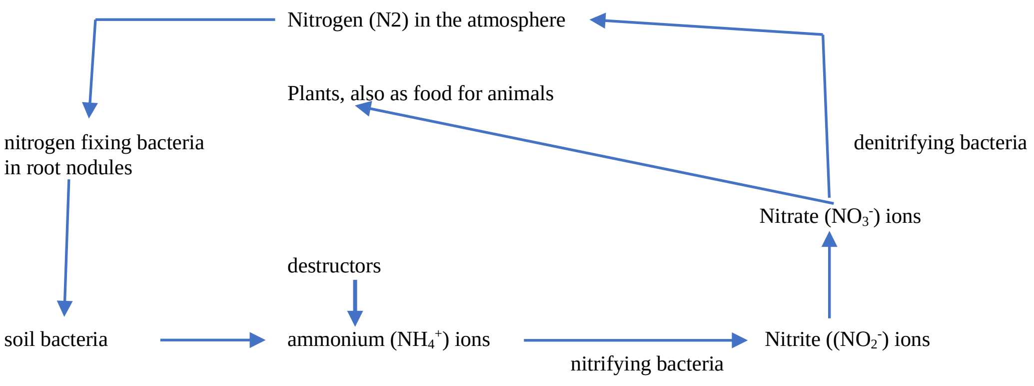
6 CO2 + 6 H2O ⇌ C6H12O6 + 6 O2

Photosynthesis

Carbon dioxide Glucose Oxygen
Water

(CO2 is **not** converted to O2 and vice versa!)

Nitrogen cycle



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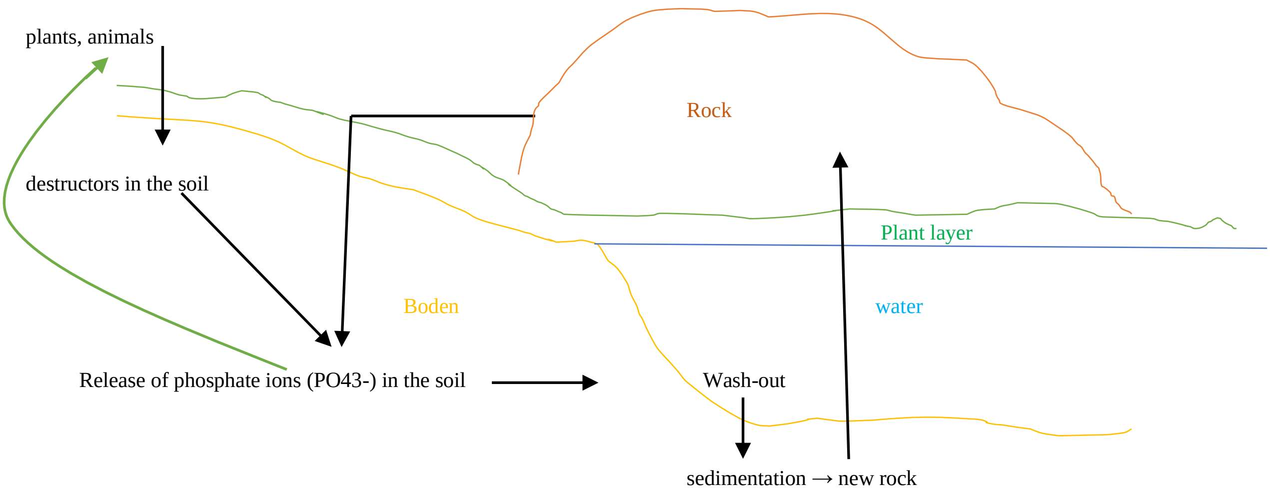
Fertilization with mineral fertilizers impairs and/or damages the soil bacteria, so that the phosphate cycle functions insufficiently or no longer.

Phosphorus cycle



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Plants need phosphate to grow.

When soils are overfertilized with phosphate, the excess phosphate is leached into the water. This causes a strong increase in algae growth in the waters. When the algae die, a lot of oxygen is needed by the destructors. If algae growth is strong, this can cause a water body to overturn. The water body contains too little O2 and too much CO2 for the living organisms that have to do cellular respiration, which leads to their death. In extreme cases, the water body is dead.

Human interventions

Population explosion

Due to improved hygiene and medical possibilities, the mortality rate of humans is decreasing. As a result, the population of the earth by humans has been increasing "super-exponentially", especially since the 20th century. This leads and led to overexploitation of natural resources and increased pollution.
This places a heavy burden on the biosphere.

→ Energy consumption has increased at approximately the same rate, disproportionately in industrialized countries.
problem of gray energy in the production of new consumer goods, which are often replaced on the basis of misconceived environmental concerns (cars, electrical appliances...)
Digitalization consumes a relatively large amount of energy.

→ Food production has increased:
Intensive agriculture.
Consequences: depleted soils due to monoculture, impoverishment of biodiversity.
Food waste

→ mobility and construction activity
compaction of soils.

→ recreational behavior

→ environmental damage
air pollution
→ global warming
acidification of the oceans
more frequent and violent storms due to more energy and as consequence higher temperatures in the atmosphere

water pollution
waste
→ plastics, micro- and nano plastics in waters and soils, which also enter the food chain.

Soil pollution, soil compaction, soil overuse.

Forest damage

Ozone problem

Formation of ozone O_3 on the ground-level

(1) $O_2 + N \rightleftharpoons 2\ NO$

(2) $2\ NO + O_2 \rightleftharpoons 2\ NO_2$

(3) $NO_2 \overset{UV}{\rightleftharpoons} NO + O^{\cdot}$

(4) $O_2 \overset{UV}{\rightleftharpoons} 2\ O^{\cdot}$

(5) $O_2 + O^{\cdot} \rightleftharpoons$ **O_3**

(6) $2\ NO \rightleftharpoons N_2 + O_2$

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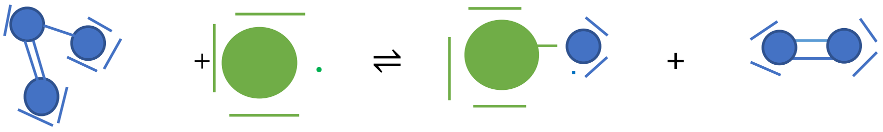
O· are oxygen radicals.
In the countryside, the reverse reaction occurs more slowly than populated and/or traveled places because the concentration of NO_x is smaller

<u>Ozone depletion in the stratosphere</u>

The ozone layer in the stratosphere protects the biosphere on Earth from the short-wave ultraviolet (UV) radiation of the sun. When the ozone layer thins or is destroyed, the shortwave UV rays can also enter the atmosphere. These rays can cause changes/damages in DNA or viral RNA, resulting in mutations.
Short-wave UV light breaks down the otherwise stable hydrocarbon compounds (CFCs). Free halogen radicals are formed.



Ozone O_3 Cl· / F· ClO· /FO· O_2

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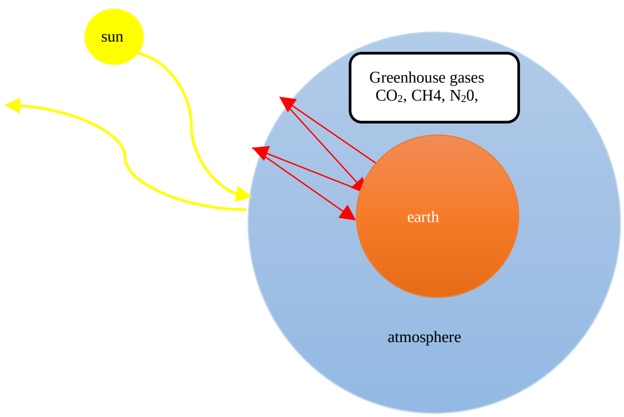
ClO· /FO· stimulate further O_3 to react.
→ Chain reaction

Normally, there is a chemical equilibrium between ozone formation and ozone depletion. If many free halogen- atoms are formed from the fluor chlorine hydrocarbon (CFC) compounds, the equilibrium shifts in the direction of the oxygen molecules (O2).
(The dots symbolize the free electrons).

Greenhouse effect

The sun emits thermal radiation (infrared IR) to the earth. A part is absorbed by the earth. A large part is normally re-radiated. Greenhouse gases reduce the radiation of the heat energy of the earth into space. The thermal radiation is also reflected by the greenhouse gases → global warming.



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Due to the greenhouse effect, the atmosphere warms up. This results in an increase of the reaction rate. Thus, climate warming also has an indirect effect on the reduction of the ozone shield.

→ Consequences of environmental pollution:

More frequent and stronger heat waves
More frequent du stronger thunderstorms
More heavy rainfall → Floods
Decrease in biodiversity
Food shortages → migration
Destruction of food cycles

→ Challenges to science and policy

Closing the open cycles
Limiting environmental damage through intelligent processes
Targets to mitigate environmental damage

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